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The Eriophyoidea of Kansas*†

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ABSTRACT

This paper is a systematic account of the Eriophyoidea in Kansas. Information is also given on life histories, distribution, behavior, economic importance, and techniques of preparing specimens. Eleven previously described genera are included in this study. Of the 29 species included in this paper, 7 are new. The described species are *A. nimia*, *Phyllocoptes microspinatus*, *Phytoptus rotundus*, *Rhyncaphytoptus boczeki*, *Vasates cercidis*, *V. dimidiatus*, and *V. michneri*.

INTRODUCTION

This work is the result of four years of collecting of Eriophyoidea in Kansas, during which time the eastern part of the state was extensively sampled at all seasons and the western part during the summer months. Twelve genera and 29 species were found in Kansas. Keys to aid in the identification of species and descriptions and figures of all species included in this study are given.

Slykhuis (1953) is largely responsible for bringing about more interest in eriophyid mites in recent years. It was his discovery of *Aceria tulipae* (Keifer) as the vector of wheat streak mosaic disease which aroused new interest in the Eriophyoidea. This discovery, and the subsequent studies of diseases of Kansas wheat and their vectors, indicated an urgent need for more information on this economically important family of mites, and this study was launched to meet it.

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Keifer's (1952) work provided the taxonomic framework and keys necessary for a survey of the Kansas Eriophyoidea. Prior to this there were no keys available and many previously described species were based upon inadequate descriptions. Host lists with good but incomplete figures have helped to make many of Nalepa's species recognizable. Nalepa (1911) gave the first reasonably adequate descriptions of mites in this group.

It is hoped that this investigation of Kansas eriophyids will form a nucleus of material that will be useful to taxonomists and those interested in agricultural or economic problems that involve the Eriophyoidea. Eriophyids have not been collected or studied previously in the Kansas area, and it is clear that many species besides those so far obtained must exist in the state. However, the material collected shows that Kansas is inhabited by several genera and many more species than was expected at the beginning of this investigation.

The needs of beginners in the study of eriophyids have been kept in mind during the preparation of this paper. The lack of detailed information on techniques of collecting and slide preparation has had a limiting effect on the number of species that could be included in this study. Only recently have techniques and mounting media been such that the agricultural or survey worker can send prepared slides to the taxonomist instead of infested plant material.

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HISTORY

The formation of galls of various types on the leaves of plants was noted and investigated as early as 1737 by Reamur (Hassan, 1928). The small wormlike inhabitants of many of these galls were thought by Reamur to be insect larvae; it was Dujardin (1851), more than a hundred years later, who reported that they were actually adult mites. Landois (1864) gave further support to the belief that these wormlike organisms were mites. Cromroy (1958) gives a fairly detailed account of early students of eriophyids.

Much credit must be given to Alfred Nalepa whose work (1887-1929) was large enough and good enough to serve as the basis for eriophyid taxonomy as it exists today. Many species that he described must be determined by host relationships, since he figured only dorsal, ventral, and lateral views of whole mites. Such data are frequently sufficient to speculate with some accuracy on species identity, but without figures of legs, genitalic structures, featherclaw, and skin structure, one can never be absolutely certain of identifications.

Since Nalepa proposed the family Eriophyidae in 1898, about 1,000 species in approximately 78 genera have been described. Keifer and Nalepa have been the major contributors.

METHODS AND MATERIALS

Collecting: Collection of eriophyid mites is relatively easy but in Kansas is seasonal, with the best results in late summer. When foliage first appears in early spring, eriophyid populations are low; about six weeks, or one generation later, they are much more abundant and relatively easy to locate with a hand lens or dissecting microscope. A few species, especially those that form clusters of twigs ("witches'-brooms") or other abnormal growths, can be collected at any time of the year by examining these abnormalities. Species that produce galls of various types or marginally rolled leaves are not difficult to find, and eriophyids are usually abundant in these deformities. Types of galls and other plant distortions made by eriophyids have been studied by Schlechtendal (1916). Descriptions of hackberry "witches'-brooms" appear in several papers on eriophyids; Keifer (1957) illustrates this condition on *Celtis occidentalis*. Injury, gall formation, and host plant distortion in Kansas are indistinguishable from the same condtion described in the papers mentioned above.

Many species of eriophyids do not cause noticeable damage to the host plant, and a careful examination of leaf surfaces is necessary to collect these species. The mites are more commonly found on the lower surfaces on and along the edges of veins, frequently with their mouthparts inserted in a vein in the feeding position. When populations are low and no plant injury attracts attention, there is still a clue that may indicate infestation. Cast skins, which look like small white streaks a bit shorter and narrower than the mites that left them, can be found scattered and in patches on the leaf surfaces.

Grasses are difficult to examine for mites because the margins of the blades roll inward and longitudinal furrows may be almost closed. Frequently, mites are most abundant at the bases of the leaves, around and under the ligules. A special plastic stage for a dissecting microscope was found to be very useful in examining grasses for mites. This stage was made of transparent plastic one-fourth of an inch thick, with a ridge of plastic one-half inch high and about two inches long cemented on it. The ridge of plastic was located so that it would extend from the bottom to the top of the visual field. A blade of grass can be drawn across this ridge and thus opened up for examination and at the same time kept in focus on top of the ridge. The plant material can be held with one hand while mites are removed with the other.

The appearance of living mites is rather variable and should be noted in making collections. They may be amber or whitish, opaque or transparent, or even chalky white if waxy secretions are present. Some species are dull shades of red and orange. The setae, especially the dorsal ones, may be black and conspicuous in living specimens although not so in cleared, mounted material.

Preserving: Collected eriophyids may be preserved in several ways. The following methods are more commonly used:

1. Heavily infested leaves or plant parts are wrapped carefully in soft tissue, put into envelopes, and allowed to dry. The dry, mummified specimens removed from such material make excellent mounts which may be superior to those made with fresh or living mites. Such dry materials should be stored in insect-proof containers and fumigated periodically.

2. Seventy percent alcohol may be used to preserve bits of twigs or leaves that are infested with mites. There are objections to this method, for usually eriophyids are difficult to handle in a liquid such as alcohol; the alcohol extracts plant pigments, becomes dark in color, and mites are often difficult to clear. Alcoholic material is not to be considered completely useless, however.
3. Keifer (correspondence) recommends a mixture consisting of 75% water, 15% alcohol, and 10% glycerin for buds and twigs. This is especially good for material that is to be sent through the mail; dry material is easily damaged.

Mounting: Making slide preparations of eriophyids is basically similar to the mounting of other kinds of mites in that they must be cleared and expanded to normal shape, then put on a slide. Since some extremely minute structures must be seen to recognize species of eriophyids, a little staining is helpful.

I have found *minuten nadeln*, pyrex depression slides, and small stender dishes to be useful equipment. The small stainless steel needles are easily mounted in glass handles by heating a solid, soft glass rod red-hot, quickly pressing in the needle and then pulling it out slightly to give a more desirable shape to the molten glass. The tip of the needle is then bent to form a tiny "foot" at the apex. Flattening of the needle to make it more like a tiny spatula also works well but is not always desirable, for such a needle picks up more medium as mites are transferred from one container to another. It is usually better to transfer as little medium as possible in handling specimens.

Recovery of collected mites varies with the methods of preservation. If the materials are in liquid, mites must be transferred individually by needles into the clearing solution. Galls or bits of heavily infested material are not difficult to break off and add to the clearing solution. If such material is not available, then mites suspended in the liquid can be pipetted into small dishes, depression slides, or glass slides and then transferred by needles into the clearing solution. Dry, mummified mites can be handled similarly by putting damage plant parts directly into the clearing solution. If the infestation is heavy, this is a workable system, even when damage to the host is not apparent. Bits of leaves, buds, or blades of grass will usually yield needed specimens. Mites can also be picked up with a needle from the dry leaf and put directly into clearing solution. When specimens are abundant, leaves or blades of grass can be tapped or shaken over a small black plate which then can be examined with the dissecting microscope. Such a plate is especially good for dry grass if specimens are fairly abundant. This saves much time in recovering specimens since they are, in most instances, about the same color as the host plant and, therefore, difficult to see.

Preparation of slides, using Keifer's (1954) solutions, requires considerable handling of mites, transferring them from one solution to another. This is not a difficult procedure, since the media do not harden rapidly. The media may, however, become thickened and sticky if too much time is taken in transferring. If this happens, a drop of fresh medium can be added to the slide to keep the medium soft. After oven drying the final mount at about forty degrees centigrade, an immediate ringing of the slide with clear lacquer is advisable. Gentle heat to spread the medium and dry the slides is recommended. A ring helps to hold the coverslip in place since even the final medium will soften under conditions of high humidity; excessive drying and crystallization are also less likely to occur in ringed mounts.

I have used a slight modification of Keifer's system. The intermediate and final media of Keifer (1954) are still used, but Nesbitt's (1945) solution is substituted for the first solution. Nesbitt's works quickly and very well in preparing dry and fresh material, but specimens must be checked frequently. It may be necessary to dilute Nesbitt's solution, because setae and featherclaws may come off if the mites are left in the undiluted solution too long. The mites should then be placed in Keifer's intermediate solution and left for a day or so before transferring them to the final mount. The intermediate medium is a good study and drawing medium because of its optical properties and mites can be rolled into position easily. This intermediate medium will not harm the specimens, even if they remain in it for long periods of time.

Viscosity and temperature of the medium are both important in making eriophyid slides. If the medium is too cold it becomes too viscous for convenient use. As mounting media age they become more viscous, but a drop or two of water added occasionally will remedy this.

Many of the problems that arise in making slides of eriophyids must be solved by the individual as they occur. The proper amount of iodine needed for staining varies from an almost saturated solution (for observation under an ordinary transmitted-light microscope) to a lightly tinted solution (if a phase microscope is to be used). Keifer (1954) gives formulae and suggested amounts of iodine in his mounting media. (See appendix for formulae of Keifer and Nesbitt.)

The following suggestions are made for placement of eriophyids on the slide: Push the mites into a compact group, if several mites are to be put on a single slide. The specimens will stay fairly close together as the coverslip settles. Orientation of a single specimen is much easier if two small needles are used to rotate or press gently on the coverslip. Forceps or needles may also be used to tap the coverslip very lightly as it settles in order to keep the mites near the center of the coverslip. Most of this is routine, and practice is very important to produce good mounts.

Mite mounting media such as Hoyer's or the polyvinyl alcohol media usually render eriophyids too clear. Occasionally eriophyids will not clear enough in PVA-L-P medium. Beer (1954) explains the formula and preparation of Hoyer's and PVA-L-P media. Actually, mounts in PVA-L-P are sometimes rather good but, when mounted from life, require a long time to clear and still do not compare favorably with the media of Keifer.

A prepared stain mountant, CMC-10S, seems to be very good and specimens can be transferred directly from Nesbitt's clearing solution to this medium. CMC-10S can be purchased from Turtox. a biological supply house. The staining properties of this medium are good, and if specimens are not cleared adequately they may become too darkly stained for phase microscopy. CMC-10S has not been in use long enough to determine the condition of specimens after a number of years. The prospects for using this mountant seem very good.

Measurements: The morphological structures measured and used in the descriptions are figured and labeled in Plate 1, which presents a general view of eriophyid morphology. In this study measurements were made as follows: *length*—caudal end to anterior tip of shield; *width*—at widest point, usually the posterior region of the shield; *leg length*—all segments included, but featherclaw not included; *rostrum*—visible portion; *dorsal estae*—entire length, and distance apart at bases being the distance between centers of the dorsal tubercles. Measurements should be used for comparative studies since some of the smaller species have been drawn to appear about as large as the largest species.

Drawings and measurements have been made using a phase contrast microscope and lightly iodine-stained specimens. The measurements of setae and rostrum cannot be taken as exact but should give some idea of size in comparison with rostra and setae of different species. Variations in these measurements may be due to the amount of staining, retraction (of rostrum), optical system used, and visual acuity of the observer, as well as actual variation that exists in the species.

SYSTEMATIC RELATIONSHIPS

Much more work must be done before definite relationships of eriophyids to other groups of mites can be established. There is a superficial resemblance to other elongate, annulate mites such as democids, nematalycids, and some of the tenuipalpids. The feeding apparatus and phytophagous habit seem to put eriophyids, tetranychids, and the tenuipalpids closer to each other phylogenetically than to other groups. The chelicerae of tenuipalpids and tetranychids are long, slender, needlelike, and protrusible with U-shaped bases. A large, protrusible, basal lobe, the stylophore, is also present in members of these two families. Eriophyids do not possess a stylophore but do have needlelike chelicerae that can be moved slightly back and forth. In the Tenuipalpidae, *Phytoptipalpus*, Tragardh has lost the fourth pair of legs. Tenuipalpids may also have elongate bodies similar to eriophyids. Annulations or markings very much like annulations can be found in all three families. Baker (1952) states that the Eriophyidae, Tetranychidae, and Tenuipalpidae have enough in common to indicate a common ancestry, but it would seem to the present author that such a relationship is a very distant one.

The anterior and transverse arrangement of genital plates is a unique characteristic of the Eriophyidae. Tenuipalpids have a transverse genital opening but it is posterior in position. Two pairs of anteriorly located legs with featherclaws are also found only in the eriophyids. A group so morphologically distinct suggests antiquity and long separation from other groups which may have had an ancestral form in common with the Eriophyoidea.

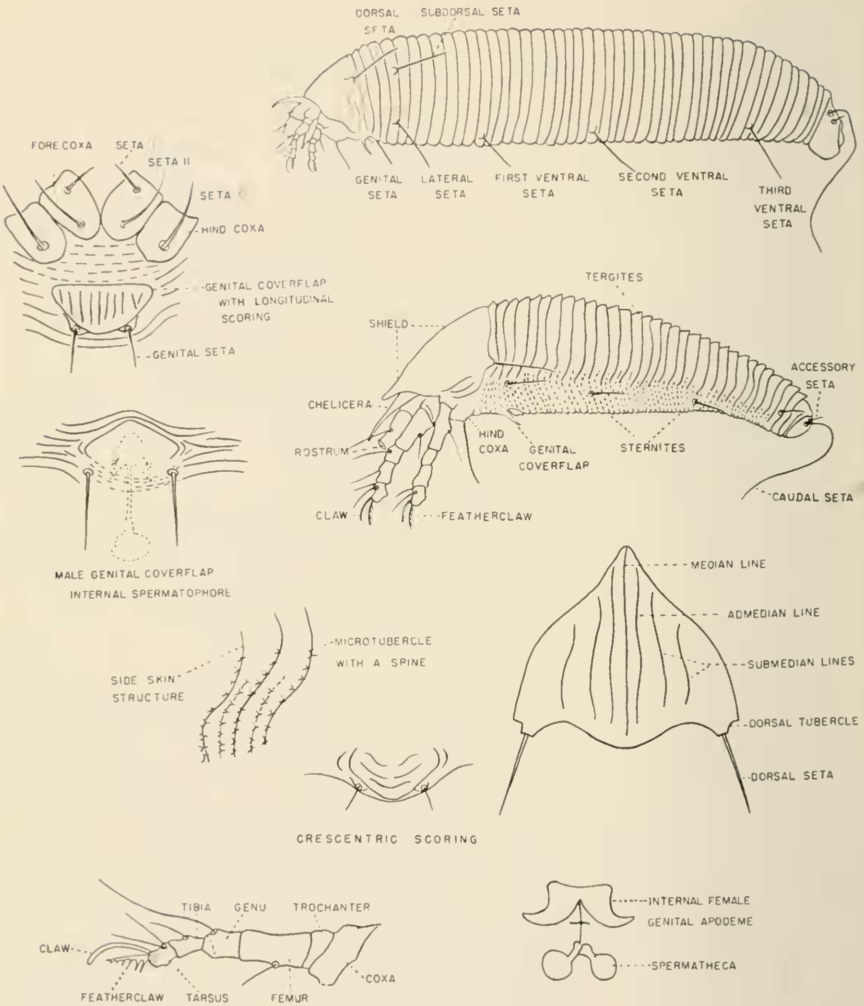


Plate 1

Wide distribution also seems to indicate an old group that has had time to spread to all parts of the world. There is still no evidence concerning the fate of the posterior two pairs of legs in eriophyids. Additional information on circumstances leading to the loss of the fourth pair of legs of *Phytoptipalpus* may help in solving the riddle of loss of two pairs of legs in eriophyids, and at such time the relationships of the latter may be much clearer.

Resemblance to other ipomorphic groups of mites, such as demodicids, is little more than similarity in shape; the similarity clearly results from parallelisms rather than phyletic relationship. Eriophyids still seem to stand as a single group, the Tetrapodili; two pairs of legs, a wormlike annulate body, proximal genitalia, and an oral stylet comprise the distinguishing characteristics of the family.

MORPHOLOGY

Hassan (1928) and Keifer (1959) provided the major papers dealing with eriophyid morphology. Hassan gave a rather general account, while Keifer's paper is a very detailed study of the gnathosoma of eriophyids.

Eriophyid morphology is discussed briefly here for convenient reference. For more detailed accounts the above mentioned papers should be consulted.

Because of its unusual body design, including the absence of posterior pairs of legs, an eriophyid's body only can be divided into two regions, the gnathosoma and the idiosoma. The gnathosoma includes the mouth opening and the adjacent appendages which form the rostrum. Several internal structures should also be considered as parts of the gnathosoma. These internal structures, according to Keifer (1959), are the pharyngeal pump, hinge, motivator, and pump brace. The gnathosoma consists chieflly of the beak or rostrum. The rostrum is made up of the palpi that form an anterior groove in which lie the following needlelike mouthparts: chelicerae, auxiliary stylets, oral stylet, cheliceral guide, and cheliceral sheath. The use of the needlelike mouthparts, which can not be retracted or extended, is described very clearly by Keifer (1959), who says that the terminal segments of the palpi telescope or fold back and make it possible for the sharp mouthparts to penetrate plant tissue.

The body of an eriophyid is elongate, wormlike, and annulate. Two pairs of legs arise anteriorly on the body. Ventrally, immediately posterior to the legs but still far anteriorly, are situated the genitalic structures of eriophyids. The genital plates are transversely arranged, somewhat similar to those of tenuipalpids, but in tenuipalpids the genitalia are posteriorly located. Baker's (1952) presumption that this difference is not as significant as one might suppose seems quite acceptable. There probably has been a coalescing of posterior body segments in the tenuipalpids, resulting in the location of the genitalia on the extreme end rather than in a more or less normal position, according to Baker.

Externally the genitalia consist of a coverflap arched posteriorly in females and anteriorly in males. Internally, female eriophyids have what Keifer calls the anterior genital apodeme. Just posterior to this apodeme are glandlike structures. The function of these glandlike structures or small sacks has not been determined definitely; it is here suggested that they are spermathecae. Males also show internal genital structures, as has been noted by Hall (1958, plate 1) among others, but they are much more difficult to see and do not appear consistently. Since males are not known for many species, little taxonomic use has been made of male characters. It may be that in some species these internal structures of males may prove useful, but at present little is known about them.

The leg of an eriophyid has a coxa, trochanter, femur, genu, tibia, and tarsus terminated by claw and featherclaw. The featherclaw with lateral rays is extremely useful as a taxonomic character at the species level; its axis may be entire or divided. The featherclaw is the empodium. Sometimes legs show considerable reduction and even loss of a segment. The subfamily Nothopodinae lacks a distinct tibia and is distinguished on this basis, plus the fusion of the anterior coxae with the suboral plate.

Setae of eriophyids are not as variable as they are in many other groups of mites, where they are often highly specialized and of many forms. It almost appears that eriophyids are so well established on the host, with overwintering and dispersal techniques solved, that they have no need for the special tactile and chemoreceptive structures present in other mites. However, the setae are sufficiently variable in size, location and number to have some taxonomic significance.

GEOGRAPHICAL DISTRIBUTION AND HOST AFFINITY

Although many parts of the world remain uninvestigated for eriophyids, they are undoubtedly present in all regions where higher plants exist. Most of the species described occur in Europe or California. A few species have been described from Java and Puerto Rico, and some economically important species are under observation in Russia and Poland.

The variety of host plants affected, the variations in life histories, the tremendous numbers of individuals, and extremely small size suited for several methods of dispersal all contribute toward world-wide distribution of this group of mites.

Some species are known to be cosmopolitan. Host requirements apparently determine ranges of other species. As preservation of specimens improves and type specimens become available, many other species may be found to be cosmopolitan. Because of the ephemeral nature of many preparations, students of eriophyids have been seriously hampered by the inadequacy or lack of type material upon which earlier descriptions are based.

Obviously eriophyids occur throughout the United States. In my personal collection are specimens from Michigan, Florida, Texas, Colorado, Nebraska, Missouri, Oklahoma, Alabama, Kansas, and California. However, in all states mentioned except California and Kansas, collection has not been intensive.

Just how host specific eriophyids are is difficult to say. Keifer (1952) states that their host relations are intimate and species nearly always show a high degree of specificity. Many species do occur on two or more closely related plant species. For example, Keifer (1952) reports that *Aceria brachytarsus* (Keifer) forms purse galls on both species of black walnuts native to California but will not attack the imported English walnut now growing in the same area. Some have host ranges extending through related plant genera; however, only *Diptacus gigantorhynchus* (Nalepa) crosses plant family lines in California, according to Keifer. It occurs on *Prunus* sp. (Rosaceae) and *Vitis californicus* Bentham (Vitaceae). *Aceria tulipae* (Keifer) is known at present from 13 different hosts in two families of plants, Gramineae and Liliaceae, both of which are monocotyledons.

Some species are known only from a single host species, but the host may be attacked by several species of eriophyids. Occasionally a single host will harbor two closely related and morphologically similar species, one of which causes conspicuous injury to, or galls on, the host while the other does not.

Host association was very important in the early history of eriophyid identification, but in recent years the discovery of more species has pointed out the limitations of relying solely on this method. It is still an important guide to identification, however, especially if the type of injury to the host is also known.

LIFE HISTORY

The life history of an eriophyid may be a simple type of development, or it may be rather complex if a deuterogynous species is concerned. A few detailed life history studies have been made by various workers. The findings of these studies, together with a general account of each type of life history, are given below.

Techniques for handling and observing living eriophyids are discussed by Baker (1939), Keifer (1941, 1942), and Rosario (1958).

SIMPLE LIFE HISTORIES

A simple life history cycle requires ten days to two weeks for completion. After hatching, two nymphal instars must be completed before the sexually mature adult state is reached. This refers to females only; it is not clear just what route males follow in the simple life history. For many species males are not known. Thus, the simple life history consists of egg, two nymphal stages, and the adult stage.

Vasates cercidis on *Cercis canadensis* L. was observed during this study and yielded the following information. In the latter part of October eriophyids were observed in abundance on the lower sides of leaves. After two nights of light freezing temperatures, mites were still abundant on the lower surfaces of the leaves. Mites were present on leaves until leaf drop and many perished with the leaves after they fell to the ground. Leaves that were not too dry, picked up from the ground, still had a few living mites on them in early November. On November 18, branches of last year's growth were brought into the laboratory and mites were found in considerable numbers under the buds (between the bud and the branch). Several mites observed in these areas were dead, but many looked normal and were alive. The mites were not active and were concentrated in the grooves and cracks between the base of the bud and the branch. On January 13, twigs were brought into the laboratory and examined by chipping material away from the outer basal areas of the bud. Hundreds of mites could be found in these areas. Most of them were light orange in color and somewhat flattened. The majority of these mites were dead and completely desiccated. In some areas such as better protected pockets or cracks, clumps of six or eight mites could be found. These mites were not dried up but appeared normal and became active after warming in the laboratory. The live mites were light amber in color and moved about very little, usually remaining in one spot and making slight movements.

As time progressed, fewer and fewer living mites could be found so that by March 16, areas that previously had eight or ten living mites now had only one or two. At this time the buds were just beginning to open. On March 31, mites were still very scarce at the bases of the buds. Weather was still cool with freezing but not severe temperatures. By April 14, the redbud trees were beginning to bloom. Eriophyids at this time were still scarce and were found at the bases of the flowers, on the receptables. Mites continued their emergence from hiding and fed especially on the basal parts of the blooms. No mites could be found at the bases of buds at this time, but they were rather numerous at the flower bases. No eggs were present as yet; adults were opaque but not chalky white. By April 26, the mites had moved to the young leaves, assembling around the distal ends of the petioles and on the undersides in angles of the veins. They were also present on new stems. Males were present but not common; two immatures were noted on one young leaf. It is not clear whether these males and immatures came from unseen eggs laid in spring or whether they had overwintered. Observations on April 30 showed scattered eggs laid on the lower surfaces of leaves along the veins. When first laid, eggs are slightly opaque with a low gloss. On May 1 the eggs looked much the same; some eggs were beginning to turn a milky white and two blackish, dark streaks could be seen inside. These dark streaks were the heavy black setae of the shield, characteristic of this species. On May 3, populations of mites were becoming established at the bases of leaves. Six to ten mites were noted at this time on some of the leaves; eggs and nymphs were observed about the base of the leaf blade and in the angles of the veins. Populations were still very low with only a dozen or so mites on some of the leaves. By the middle of May the new generation, including nymphs and adults, was established and it seemed that about every month a new generation was produced. There is apparently considerable overlapping of generations, but it seems that at least three generations are produced in the summer months. Late in the summer many mites become sequestered in protected areas where buds are produced and, as already noted, many remain on and perish with the leaves.

My observations are in harmony with other life history studies of eriophyids. There is the probability that a greater percentage of overwintering forms die and that more generations may be produced by this Kansas species than by the other species studied. Summer temperatures in Kansas are high, frequently in excess of 100°F which may account for the several summer generations.

One other Kansas species, *Aceria slykhuisi* Hall, was observed rather closely in this study. The host of this species is *Buchloe dactyloides* (Nuttall). Hall (1958) gives a brief account of relationships to the host and to other mites (tarsonemids) that commonly occur on the same host. To observe the mites, samples of grass were obtained from Fort Hays Experiment Station where outdoor test plots of *Buchloe dactyloides* were maintained. In the summer of 1954 four sprouts of this grass were placed in seedling flats in the greenhouse. These samples of grass seemed free of eriophyids; there was no evidence of mite damage to the host. Most of this grass died down, but some was maintained through the winter. As runners were put out in April of 1955, "witches'-broom" symptoms began to appear and eriophyids were numerous in these deformities. More abnormal tufts of grass formed and eriophyids became exceedingly numerous in these tufts. Predatory phytoseiid mites were occasionally seen in these cultures. By May 25, populations of tarsonemids, *Steneotarsonemus spirifex* (Marchal), were seen in the "brooms," coexisting with the eriophyids. The tarsonemids became numerous but just what effect they had on growth of the host or on the eriophyids is not clear. It is certain that the "witches'-brooms" and the eriophyids appeared before the tarsonemids and it thus is apparent that the plant growth deformity is caused by eriophyid feeding.

Vasates dimidiatus, described in this paper from *Populus deltoides* Marshall, was observed from egg to adult stage. Eggs hatched into nymphs in approximately eight days. The egg to adult period was about two weeks. (For relation to host see the description of this species.)

In 1957, Minder, a Russian worker, carefully studied the life history of *Eriophyes pyri* (Pagenstecher) which infested pear orchards and caused as much as 95 percent crop loss. The more significant points in his study are given below:

The egg to adult period was 20 to 25 days. Only two generations per year were noted and overwintering began in June. Females and a few nymphs overwintered in the buds. Males were not observed in the first generation and constituted only 0.5 percent of the second generation.

Minder also mentions the manner of gall formation by the host plant in response to the feeding of *Eriophyes pyri* (Pagenstecher). Osmotic pressure of fluids in the leaves is mentioned by Minder as a possible factor in plant resistance to mite attack.

COMPLEX LIFE HISTORIES

The complex life history was not understood until Keifer (1942) discovered two types of females in the buckeye rust mite, *Oxypleurites aesculifoliae* Keifer. Later in his generalized report of the life cycle of deuterogynous species, Keifer mentioned the existence of one female, the protogyne, which is associated with males; the other structurally different female is the deutogyne which is specialized for hibernation or aestivation and is not associated with males. The protogyne or primary form is morphologically similar to the male and occurs more commonly on the leaves of the host plant. Keifer states that deutogynes appear in response to leaf maturation or to the coming of lower fall temperatures. Deutogynes do not reproduce in the year that they develop; they feed on the leaves, then withdraw to bark crevices or lateral buds where they overwinter. Deutogynes will enter diapause after feeding regardless of the season. Overwintered deutogynes come out of hibernation in the spring and lay eggs on the new leaves; these hatch into males and protogynes. The primary females (protogynes) then lay eggs which produce primary or both primary and secondary females (deutogynes), as well as males.

In his studies of the buckeye rust mite in Marin County, California, Keifer found that deutogynes became active in late winter, left their hibernating quarters on twigs, and when buds swelled in February, penetrated beneath the outer scales. There they fed on the green tissues of the inner scales. With the development of the early spring leaves, the deutogynes laid eggs which hatched into nymphs, producing primary mites of both sexes on the leaves. The primaries soon began active reproduction of additional primary mites. Beginning the last of April or early May, Keifer found new deutogynes appearing among the primary types. When fully fed, these deutogynes traveled down the stem six inches or more. There they crawled into crevices or other shelters on the previous season's wood. Thus deutogynes appeared to abandon the leaves during June and July. The primary females remained on the leaves and green tissue and perished with it, although reproduction had almost ceased by early July.

Putman (1939), working with another deuterogynous species, *Vasates fockeui* (Nalepa and Trouessart) suggested that hardening of foliage may have something to do with the production of overwintering forms. Keifer does not disagree with this idea. However, it is Putman's belief that over-wintering females may be fertilized before hibernation. This idea came from his observation that unfertilized protogynes produced only males while over-wintering females (deutogynes) produced both males and females. Thus, we see that in *V. fockeui*, protogynes are arrhenotokous. Since there is little proof available on fertilization or lack of it one can not be certain that deu-terotoky exists in eriophyids. Burditt (1963) indicates in *Phyllocoptruta oleivora* (Ashmead) and *Aculus pelekassi* Keifer that fertilized females produced male and female offspring and unfertilized females produced only males. Here then are two more examples of arrhenotoky.

Shevtshenko (1957) has given an interesting account of the life history of another deuterogynous species *Eriophyes laevis* (Nalepa), summarized below.

The egg to adult period was 23 to 25 days. Two and sometimes three generations of protogynes were produced by *Eriophyes laevis*. Deutogynes appeared in July with maximum number in August. The deutogynes immediately left galls and went to the overwintering sites. Eggs were laid by deutogynes only after overwintering, and these eggs produced female protogynes. Protogyne eggs developed into protogynes, deutogynes, and males. Males appeared early in the second generation. Shevtshenko did not observe mating but suggested parthenogenesis in the deutogynes and spermatophore formation in protogynes.

There is some recent evidence of ovoviviparity in three species. Shevtshenko (1961) mentions this in *Eriophyes laevis* (Nalepa); his drawing shows a female with two nymphs inside the body. The two eggs from which the nymphs hatched are also shown inside the female's body with the two nymphs. He does not indicate whether this ovovivipaparous female was a protogyne or a deutogyne.

I have observed the same thing in *Vasates quadripedes* Shimer. A protogyne female on a prepared slide shows two nymphs and two empty eggs inside the body (plate 27). This method would obviously reduce the number of young produced by a single female and may explain why the ovoviviparous habit is not widespread in eriophyids. Fewer offspring would reduce the possibility of survival and production of another generation.

Burditt, Reed, and Crittenden (1963) came across another example of ovoviviparity in *Phyllocoptruta oleivora* (Ashmead). Although this is not reported in their paper, D. K. Reed sent me photographs of three female specimens with a single nymph inside the body of each female.

The senior author Burditt (1963) reports a single observation of copulation in eriophyids. During copulation, the female almost completely covered the male, according to Burditt. This is the complete and, to my knowledge, the only record of mating in eriophyids. D. K. Reed indicates (correspondence) that round-the-clock observations are being made in the USDA laboratories at Orlando, Florida. I have no information concerning the results of this work.

In general, the life history studies by Baker (1939), Putman (1939), Keifer (1942), Minder (1957), and Shevtshenko (1957) are in agreement. Some differences do exist in that most authors report that deutogyne eggs produce only females, but Putman found that deutogyne eggs produced males and protogynes and unfertilized protogynes produced only males. There may well be specific or generic differences in such matters.

A number of points (for example, mating and sex determination) are still not explained. The exact role of eriophyid males is still uncertain. Mating has been reported from only one observation (Burditt, 1963). Males are present in populations of many species, sometimes abundant, sometimes scarce or absent. Deutogynes, the overwintering females, in most cases produce only female protogynes, but in at least one case (Putman, 1939) deutogynes seem to produce both males and female protogynes. Shevtshenko (1957) suggested spermatophore formation and E. W. Baker (correspondence) also speculates that males deposit spermatophores and females pick them up. This unsolved point in eriophyid life histories is a challenging problem which merits immediate attention. I feel that spermatophore formation and transfer is the probable mechanism of fertilization in eriophyids.

I have noted occasionally in males some internal genital structures that occupy the same relative position as female genital apodemes and spermathecae. The function of these structures in the male is not known. From the structure of these internal genital parts in the male (see *Aceria slykhuisi* Hall, plate 13, and *Abacarus sporoboli* (K.), plate 2), it seems that the anterior end is modified for attachment or for holding. Since mating is still not fully described in eriophyids, I judge that these anterior recurved or barbed structures may be part of a spermatophore and perhaps aid in removal of the spermatophore from the body of the male. These internal male genital structures are posteriorly modified into glandlike bodies that may be parts of the supposed spermatophore.

It is easy to understand why, in some instances, two types of females belonging to the same species were described as two different species. For example, in the life history of *Oxypleurites aesculifoliae* Keifer the deutogynes were described as *Phyllocoptes aesculifoliae* Keifer in 1938. Two months later the primary type was named *Oxypleurites neocarinatus* Keifer. A great deal of confusion in eriophyid life histories was cleared up by the recognition of deuterogyny. Here then is another example of research of fundamental nature on non-economic species leading to the solution of a problem in an economic species. In this case, the pear leaf rust mite, *Epitrimerus pirifoliae*

Keifer, was better understood with the discovery of two kinds of females in *Oxypleurites aesculifoliae* K.

BEHAVIOR

There is considerable variation in the behavior of the species of eriophyids. Virus transmission work, mite dispersal studies, and life history observations have emphasized similarities and differences.

Dispersal of eriophyids is discussed here because their behavior in response to growth or death of the host determines whether they stay on that host or take a position that will cause them to be blown or carried to another area and possibly to an uninfested host. Three methods of eriophyid dispersal are known: wind, insect, and man (by budding). Wind is undoubtedly the chief means of dispersal; dispersal by insects is probably second in importance. The transfer of specimens from one host to another by man, in budding or grafting plants, is of little importance and would involve only a few economically important species.

Eriophyids that live on grasses, especially wheat, do not have survival sites such as buds and bark, and they must find other survival sites. This usually means leaving the host. Gibson and Painter (1956) give evidence that wheat kernels infested with eriophyids are the source of mites infesting new wheat seedlings produced by such kernels. As infested kernels of wheat drop to the ground and sprout the mites frequently move directly from the kernels to the new wheat seedlings. Therefore, it seems that mite-infested kernels are important survival and overwintering sites. Gibson and Painter (1957) state for *Aceria tulipae* that, as plants begin to die, the mites migrate upwards with thousands concentrating on the tips of leaves. There they crawl upon one another, often forming chains of several individuals connected by their anal suckers. In the greenhouse many of these chains separated from the mass and fell to the soil below. Mites in the field are readily air-borne and undoubtedly this is the primary means of dissemination. Air-borne specimens of *Aceria tulipae* have been collected 150 feet above ground and one to two miles from the nearest wheat fields where the species would normally be found (Pady, 1955).

A kind of behavior seen in nearly all species of eriophyids consists of holding the body perpendicular to the leaf surface and adhering to the surface by the anal sucker or by sticky secretions. The posterior end of an eriophyid mite is bilobed and perhaps can be used in a pinching action to cling to the leaf surface. In this perpendicular position they are more likely to be blown from the leaf surface. This also seems an advantageous position for attachment to insects as they pass by.

Dispersal by insects was also noted by Gibson and Painter (1957) who observed mites attached to the body of an aphid. This method of dispersal probably occurs frequently in the field and could be important in getting mites to volunteer wheat in fringe areas of a wheat field. Spots of volunteer wheat that are not cut and plowed may be important survival sites. Attachment to insects may be the chief means of reaching alternative hosts since the aphid may go directly to another host.

Movements of mites on woody plants vary with the seasons. As new growth appears in the spring, mites come out of overwintering sites and move upward. This upward movement is negative to gravity according to Shevtshenko (see Life History section). The season when the buds swell seems to be the time that upward migrations begin and, as this is synchronized with rising temperature, it may trigger the movement. In the fall, mites on trees and shrubs move downward or toward the last year's growth to sequester themselves in cracks of bark or in buds for overwintering.

Eriophyids can move about rather quickly even though they are extremely small. Minder (see Life History section) gives the rate of movement as a maximum of 10 to 15 mm per minute. This indicates that they can move easily to new growth and spread to all parts of a single tree or shrub without the aid of special dispersal methods such as wind or insects.

Response to light may be involved in movement. Negative reaction to light has been reported by Rosario and Sill (1958) who were able to transfer *A. tulipae* from one leaf to another by directing a beam of light at them. A flashlight (cold light) seemed to work as well as a 50-watt incandescent light. Movement of the same species to leaf tips, as described above, shows that at certain times or under certain circumstances other factors counterbalance the response to light.

Ordinarily eggs of eriophyids are scattered on the leaf surface or along veins. On grasses, eggs may be placed in the longitudinal furrows and more often at the base of the leaf under and near the ligule. Eggs are apparently sticky and remain attached where they are placed, even when laid on the tips of plant hairs (see *Rhyncaphytoptus boczeki* discussed below). Nymphs feed and then attach themselves to the leaf surface; they appear to be stuck to the surface and as they molt, the cast skin, appearing as a white streak, is left at the place of attachment.

Little is known about the manner of excretion in this group of mites. There is no evidence of excrement, even inside a small gall where hundreds of mites are living. Since plant juices serve as food for eriophyids, excrement may be excess fluid passed on through the digestive tract and this may be absorbed by the plant. If the excrement is fluid, this would be very difficult to see on the leaf surface.

Due to their small size and habit of living in protected areas such as galls, cracks, and buds, eriophyids have little need for special defense mechanisms. Most of the galls are lined with an erineum and the opening into them is so completely blocked by these plant hairs that any predator larger than an eriophyid would have difficulty entering the gall.

I observed that *Rhyncaphytoptus boczeki* has a method of oviposition and molting which seems to give some protection from predators. This species occurs on *Celtis occidentalis* L. Eggs are laid singly and in groups of two or three at the tips and near the tips of plant hairs, completely removed from the leaf surface. After hatching and feeding, most of the immatures crawl back up the plant hairs, attach their posterior ends to the hair and extend the rest of their bodies out into space parallel to the leaf surface but well above it. Some individuals attach parallel to the plant hairs or along them rather than extending their bodies. Molting occurs in these unusual positions. I have observed possible predators (e.g. phytoseiids) walking about on the leaf surface, passing under these eggs and molting forms, apparently without sensing their presence.

MORPHOLOGICAL AND BEHAVIORAL ADAPTATIONS

Morphologically eriophyids seem extremely well adapted to their environment. Size and body shape are such that they can exist in abundance in protected spaces of such small size that almost all other arthropods are excluded. Good protection and easy dispersal by wind to other host plants seem to make this a highly successful family. Undoubtedly protection and good dispersal, which are important factors of survival in any species, are possible because of the small size.

It is interesting to note that eriophyids living in galls of various sorts and those living as vagrants on leaf surfaces are different in appearance. Those living in galls have bodies that are evenly contoured and lack the bizzare undulations, ridges, and folds seen in many vagrant species. I believe that vagrant forms with these folds and undulations have evolved into the evenly contoured types that live in galls. The body folds and ridges would certainly be disadvantageous to them in small galls or tightly rolled leaf margins. With spacial restrictions of the microhabitat imposed by the confining walls of such galls, populations get to be so large that the mites appear to be literally packed into such areas. Complex body form would be a serious disadvantage under these circumstances.

It is also possible that gall forms could be evolving into the free living form, but this seems less likely because the formation of galls must have come about after free living mites became established on plants. Mechanisms of producing galls probably evolved in vagrant species, and this was followed by morphological adaptation to this microhabitat.

Keifer (1966) discusses the subfamily Aberoptinae which contains species capable of mechanically damaging the host plant. Most damage caused by eriophyids is biochemical in nature but at least two species seem capable of causing mechanical damage. *Aberoptus samoae* K. has spatulate foretibiae and *Cisaberoptus kenyae* K. has a rostrum that is quite distinct. These structures seem well adapted for the habit of burrowing under the leaf surface. *C. kenyae* K. does just this and it is not known exactly what *A. samoae* K. does, but it certainly seems equipped to cause mechanical damage.

The possession of only two pairs of legs is perhaps of some benefit to eriophyids. They can move about easily among plant hairs and in furrows with the two pairs of anterior legs dragging the elongate body. The legs are situated so that movement is accomplished by reaching forward and pulling, without lateral extension or movement of the legs which would hamper movement on pubescent or furrowed leaf surfaces. The loss of legs is perhaps another adaptation which has made it possible for eriophyids to occupy galls.

Body setae are directed posteriorly which would also be an advantage in forward movement among plant hairs or furrows. Occasionally shield setae are directed anteriorly or medially, but these are invariably shorter, do not extend much beyond the body limits, and would therefore not seem to interfere seriously with movement.

Eriophyids lack special sensory setae. The abundance of food and easy dispersal seem to reduce the need for them. Featherclaws of eriophyids are the only setae that show much modification, and their exact function is not known. Judging from the appearance of featherclaws, I would say that they could be tactile or adhesive in function. Featherclaws are possibly useful in locating feeding sites such as veins.

Behavioral adaptations of eriophyids are directed along three lines: overwintering, protection, and dispersal.

Overwintering adaptations apparently have been made in response to seasonal (or climatic) changes. Regardless of the exact stimulus, a method has evolved of surviving the season of plant dormancy. In some species, females and a few nymphs overwinter in small protective cracks or in buds and start new populations in the spring as new growth begins. A higher degree of specialization is seen in deuterogynous species which feed and immediately go into overwintering sites, remaining inactive until next spring when they lay eggs. Deuterogyny would seem to be more beneficial to species living on deciduous trees or plants with a short growing season. A new generation is assured by the overwintering deutogynes even though leaf drop occurs with many individuals dying on the leaves. Actually there are no deuterogynous species known from gymnosperms or broadleaf evergreens. Species living on these plants are probably not challenged by the problem of overwintering because of the usually evergreen foliage. No deuterogynous species are known from broadleaf evergreens.

A presumably protective habit of one vagrant species, *Rhyncaphytoptus boczeki*, is the laying of eggs on the apices of plant hairs rather than on the leaf surfaces. Molting also takes place well above the leaf surface where discovery by predators is less likely.

An adaptation that undoubtedly enhances dispersal is the mass migration of eriophyids to the uppermost leaf apices where they form chains of individuals which break off and are readily airborne. Dispersal resulting from attachment to insects is perhaps accidental, but it does seem that the habit of raising and holding their bodies perpendicular to the surface of the leaf with their legs free would make it much easier for eriophyids to attach to insects and be carried to other plants.

Morphological and behavioral adaptations of eriophyids have reached what appears to be a rather stable condition. This could be due to severe pressures of the environment. Slight changes in morphology or behavior would be eliminated from the population quickly and thus would favor the maintenance of a group with uniform characteristics. Such a situation, prevailing over a long period of time, would also explain the obscurity of the ancestry of the group as well as the large number of similar species in a small number of genera.

ECONOMIC IMPORTANCE

Direct damage to fruit and foliage as well as the transmission of virus diseases to host plants by eriophyids emphasize the economic importance of the ubiquitous group. The following are four virus diseases known to be transmitted by eriophyids: current reversion, fig mosaic, peach mosaic, and wheat streak mosaic. Losses due to these diseases are great, and when added to those caused by mites feeding on foliage and fruit, the amount is millions of dollars annually. There are reports of crop losses of pears as high as 95 percent (Minder, 1957) due entirely to eriophyid infestations.

Economic papers on eriophyids are very numerous and a complete account is not given here. Only occasionally are losses estimated in dollars. In Kansas, *Aceria tulipae* (Keifer) is the most important species economically. Kantack and Knutson (1958) cite losses due to wheat streak mosaic vectored by *Aceria tulipae* as $30,000,000 in 1949 and $14,000,000 in 1954. Considering all wheat growing areas, these figures would be increased considerably, at least enough to warrant exhaustive studies of this species to determine the best methods of control. No estimates are available on losses due to other virus diseases carried by eriophyids.

The transmission of peach mosaic virus by *Eriophyes insidiosus* Keifer and Wilson was shown first by Wilson, Jones, and Cochran (1955). This discovery came after some 8,000 tests had been made, using about 150 species of suspected arthropods. About 20 years of research preceded this discovery. Peach mosaic occurs in California, Colorado, Texas, Oklahoma, and Arkansas. The vector was easily collected in all these areas. It is likely that this virus also occurs in Kansas, but it has not yet been reported.

Aceria ficus (Cotte), the vector for fig mosaic common in California, has not been collected in Kansas. No estimates of losses are given for fig mosaic. Currant reversion disease, carried by the currant big bud mite, *Cecidophyes ribis* (Nalepa), is of no importance in Kansas.

Undoubtedly there are other virus diseases vectored by eriophyid mites, and some species, in addition to *Aceria tulipae* (Keifer), may yet be found to have a role in streak mosaic of wheat. Since eriophyids occur on several grasses and many trees and shrubs, often with little or no damage visible on some hosts, they should at least be kept in mind as potential virus transmitters and as a group of potential economic importance.

Control of eriophyids is rather difficult due to the small size and, frequently, the inaccessibility of the mites on the host. Kantack and Knutson (1958) summarize control studies of this mite. The highest degree of control is reported as 90 percent using Shell OS-1808 which has a very low residual action. Another problem in controlling a species such as *Aceria tulipae* (Keifer) is the presence of alternate host grasses adjacent to, as well as remote from, the wheat fields. Good residual acaricides would possibly help to eliminate this problem. At present such acaricides are not available, and even if they were, the new growth would have no protectant.

Fruit trees are about the only woody plants on which control studies have been made. Boyce (1942) and Spencer (1950) indicate that good control of eriophyids on fruit trees can be achieved using various sulfur or sulfur-containing materials. Spraying was found to be more effective than dusting. The time of spray application is very important in that mites are more easily killed when exposed and moving about.

A number of papers dealing with wheat streak mosaic have been produced at Kansas State University. A list of these publications may be obtained by writing H. W. Somsen, Entomologist, U.S.D.A., Entomology Research, Kansas State University, Manhattan, Kansas.

Boczek (1966) published an extensive bibliography of mites affecting plants and stored food products. This is a good source of information for the researcher interested in economically important species.

SYSTEMATIC ACCOUNT

Until recently the family Eriophyidae was divided into eight sub-families. Keifer (1964) pointed out that three distinct structural groups are apparent and proposed three families under the Eriophyoidea. The following family descriptions are taken from Keifer (1964). Generic examples are given in his Eriophyid Studies B-11.

PHYTOPTIDAE Murray 1877

Three or four setae on cephalothoracic shield, the rear pair pointing straight or diagonally forward; a pair of subdorsal abdominal setae a short distance behind shield, present or absent. Rostrum usually large and evenly down-curved, with apical recurved portion of oral stylet shorter than base plus pharyngeal pump. Legs with all segments and with anterolateral spur on tibia present or absent. Female genital coverflap never ribbed; anterior internal apodeme always moderately long; spermathecae short or long-stalked, but with stalks or tubes projecting forward first and then recurved. Habit: gall formers, bud mites, rust mites, or leaf vagrants.

ERIOPHYIDAE Nalepa 1898 (as here restricted)

Body either wormlike or fusiform, often flattened. Two or no setae on cephalothoracic shield; setae when present on shield located from central area to rear margin, pointing in various directions according to type. No subdorsal abdominal setae. Rostrum large or small, either down-curved or projecting straight down; apical portion of oral stylet shorter than base plus pharyngeal pump. Legs usually with all setae and segments, less often with tibia fused to tarsus, never with lateral tibial spur. Female genital coverflap usually with a pattern of ribs; anterior internal apodeme either projecting ahead from base line or short and transverse; spermathecae short-stalked the stalks or tubes either projecting laterally or posteriorly from origin. Habit: gall formers, bud mites, leaf or green stem vagrants, rust mites.

RHYNCAPHYTOPTIDAE Keifer 1961

Body stout or elongate, fusiform and tapering, not flattened. Cephalothoracic shield with two or no setae, when present the setae located near rear shield margin and pointing forward in some degree. No subdorsal abdominal setae. Rostrum always large, usually abruptly bent down from near base, and tapering; apical portion of oral stylet longer than base plus pharyngeal pump. Legs usually with all six segments, or tibia or patella absent; femoral seta and others frequently absent; never with lateral tibial spur. Ribbing on female genital coverflap usually but not always absent; internal apodeme extending forward, broad or acuminate; spermathecae short-stalked, the stalks extending laterally or to rear. Habit: rust mites or leaf vagrants.

KEY TO FAMILIES

1. Three or four shield setae present, rostrum large, evenly curved downward; apical recurved portion of oral stylet shorter than base plus pharyngeal pump .... Phytoptidae

1. Two or no shield setae present; rostrum abruptly bent down from near base, evenly curved downward or extending straight down; apical portion of oral stylet longer or shorter than base plus pharyngeal pump 2
2. Rostrum large abruptly bent down near base; two shield setae, if present, pointing forward in some degree; apical portion of oral stylet longer than base plus pharyngeal pump .... Rhyncaphytoptidae
2. Rostrum large or small, down curved evenly or extended straight down; two shield setae, when present, variable in position and direction; apical portion of oral stylet shorter than base plus pharyngeal pump .... Eriophyidae

KEY TO KANSAS GENERA

1. One or two frontal shield setae present in addition to the usual posterior dorsal setae .... *Phytoptus*
1. Only dorsal setae present or no shield setae present 2
2. Featherclaw divided .... *Apodiptacus*
2. Featherclaw not divided 3
3. Rostrum large, projecting straight down; chelicerae abruptly bent .... *Rhyncaphytoptus*
3. Rostrum not always large; chelicerae evenly curved 4
4. Abdomen bearing three longitudinal wax producing ridges ...... *Abacarus*
4. Abdomen having more than three wax producing ridges or such ridges lacking 5
5. Abdomen bearing four longitudinal wax producing ridges .... *Mesalox*
5. Wax producing ridges not present 6
6. Lateral toothlike projections or lobes present on the abdomen .... *Oxypleurites*
6. Lateral toothlike projections or lobes not present on the abdomen 7
7. Shield without setae .... *Cecidophyopsis*
7. Shield bearing two or more setae 8
8. A sublateral groove present on the abdomen .... *Platyphytoptus*
8. Without a sublateral groove on the abdomen 9
9. An anterior shieldlike lobe over the rostrum; tubercles ahead of rear margin of shield, setae directed anteriorly and usually converging .... *Phyllocoptes*
9. An anterior shieldlike lobe over the rostrum present or absent; tubercles on or in front of rear margin of shield, dorsal setae directed caudad if shield lobe is present and variable in position if shield lobe is absent 10
10. An anterior shieldlike lobe over the rostrum; dorsal setae on or

very near rear margin of shield, dorsal seta placed somewhat laterally and diverging caudad or occasionally more medial in position and converging slightly caudad .... *Vasates*
10. Anterior shield like lobe over the rostrum thin, minute, or absent; dorsal setae variable 11
11. Shield setae on rear margin of shield, directed caudad .... *Aceria*
11. Shield setae in front of rear margin of shield, directed anteriorly or posteriorly .... *Eriophyes*

Plate Symbols

The following symbols refer to the structures in plates 2 to 32.

AP—Anterior genital apodeme. API—Internal female genitalia. DA—Dorsal view of anterior section of shield. ES—Side skin structure. EV—Ventral skin structure. F—Featherclaw. Fl—Featherclaw and tarsus. FD—Featherclaw of deutogyne. GF—Female genitalia, ventral view. GFl—Female genitalia and coxae from below. GM—Male genitali.a GMl—Male genitalia and coxae. GMS—Male genitalia, spermatophore. L—Left legs. Ll—Left anterior leg. LT—Tartus and associated structures. R—Rostrum. S—Side view of adult mite. SA—Side view of anterior section of mite. SP—Side view of posterior section of mite. SPl—Side view of protogyne. STH—Spermatheca. V—Ventral view of mite.

LIST OF PLATES

ERIOPHYIDAE

Genus **Abacarus** Keifer

Abacarus Keifer, 1944, Bull. California Dept. Agr., 33:28.

Type of genus: Calepitrimerus acalyptus Keifer, 1939, Bull. California Dept. Agr., 28:490 (by original designation).

Discussion: In this genus the tergites form three dorsal, longitudinal, wax-bearing ridges. The central ridge is shorter than the laterals and terminates in a slight, dorsal depression. The setae, legs, and rostrum are not distinctly different from other genera. The genus *Calepitrimerus*, from which the type was segregated is similar to *Abacarus* but has the setiferous shield tubercles ahead of the rear margin of the shield. In *Abacarus* these tubercles are on the rear margin of the shield, with setae directed caudad.

This genus has three species; two from California and one from Austria. At present the genus is of no economic importance.

Abacarus sporoboli (Keifer)
(Plate 2)

Abacarus sporoboli Keifer, 1965. Eriophyid studies B-16. Bureau of Entomology, California Dept. Agr., p. 11.

Type locality: Some point in Sanborn Co., South Dakota.

Type host: Sporobolus airoides (Torr.) (Gramineae-Agrostidae) dropseed.

Relation to host: Keifer indicates the mites are probably leaf vagrants. In Kansas this species occurs on *Sorgum halepense* (L.) Pers. and there is no apparent damage to the host. On *S. halepense* mites are found scattered along the length of the leaf in the longitudinal furrows.

Discussion: Two species are rather similar to *Abacarus sporoboli* K. Differing in the shape of the female genital cover flap, featherclaw and papillose shield is *hystrix*. Another species, *afer*, from African coffee may be distinguished by noting that *sporoboli* has coarser granules on the shield, lacks side branches on the admedian lines, and 6-rayed featherclaw.

Kansas record: Stafford Co., Kansas, 30 mi. W. of Hutchinson, U.S. hwy. 50, south, Aug. 14, 1955, C. C. Hall. Collected from *Sorgum halepense* L. (Gramineae) Johnson grass.

Genus Aceria Keifer

Aceria Keifer, 1944, Bull. California Dept. Agr., 33:22.

Type of genus: Eriophyes tulipae Keifer, 1938, Bull. California Dept. Agr., 27:185 (by original designation).

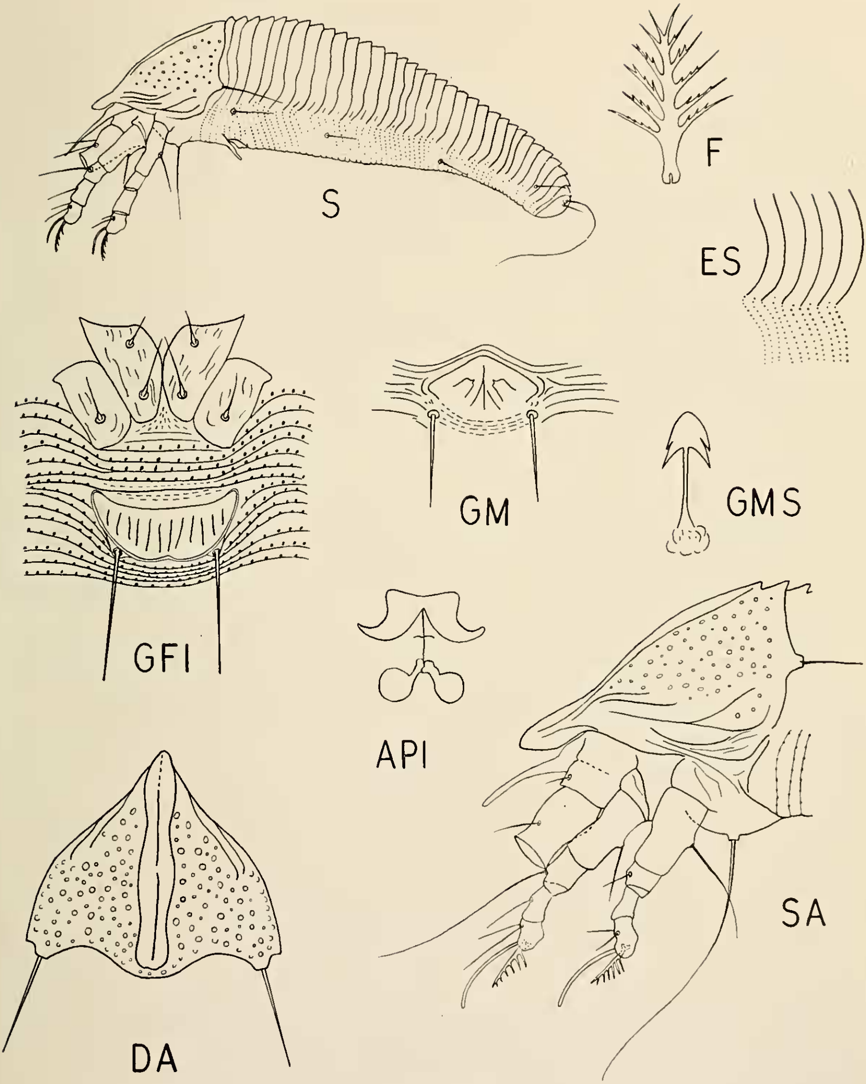
Discussion: This rather large genus includes wormlike mites with the dorsal setae situated on the rear margin of the shield and directed posteriorly. The rostrum is somewhat variable in size, but it is usually small and the chelicerae are always evenly curved. The tergites and sternites are similar with occasionally fewer tergites than sternites in the last third of the abdomen. The dorsal tubercles are frequently located with their long axes transverse to the body; this tends to cause the dorsal setae to diverge posteriorly. The axis of the featherclaw is undivided but variable in structure and number of rays.

This is a cosmopolitan genus which infests both mono- and dicotyledonous plants. All types of eriophyid injuries are produced by members of this genus, including the transmission of a plant virus disease by *Aceria tulipae*.

KEY TO THE SPECIES OF Aceria IN KANSAS

Aceria in Kansas contains more species than any other genus presently known in the area. Frequently a host association plus the type of damage is all that is needed to identify a species coming from a locality, especially if that area has been collected and certain species are known to occur there. For quick identification of Kansas *Aceria* a key is given below:

1. Featherclaws 3- to 4-rayed 2
1. Featherclaws 5- to 7-rayed 4



(Plate 2)

2. Featherclaws 3-rayed; shield with incomplete median and admedian lines (Microtubercles weakly expressed) .... *caryae*
2. Featherclaw with 3 or more rays; shield pattern lacking 3
3. Featherclaws 3-rayed; no markings on genital coverflap (Microtubercles distinct, rounded, and located in center of annular rings) .... *erineus*

3. Featherclaws 4-rayed; 10 or 11 longitudinal marks on genital overflap .... *nimia*
4. Featherclaws 5-rayed 5
4. Featherclaws 6- or 7-rayed 10
5. Genital flap with markings in two ranks (Shield with median, admedian, and submedian lines present; microtubercles very small, placed near posterior margin of annular rings; on (Opuntia) .... *cactorum*
5. Genital flap without markings or with markings in one rank 6
6. Genital flap without markings (Shield rounded and without markings; on *Celtis*) .... *celtis*
6. Genital flap with 6 or more longitudinal markings in a single rank 7
7. Genital flap with 6 or 7 longitudinal markings; shield with complete median and admedian lines, incomplete submedian lines; microtubercles oval and centrally located in annular rings (on *Ulmus*) .... *parulmi*
7. Genital flap with more than 7 longitudinal markings; shield smooth or with a pattern; microtubercles present or absent 8
8. About 13 longitudinal markings present on coverflap; shield smooth (Microtubercles posteriorly placed in annular rings, rounded, spinules present; on alfalfa) .... *medicaginis*
8. About 10 longitudinal markings present on coverflap; shield pattern present 9
9. Shield with median line indistinct, area between complete admedian lines filled with many broken lines, submedian lines irregular; microtubercles weakly expressed and in posterior region of annular rings .... *lepidosparti*
9. Shield with median line distinct but broken, admedian lines complete, submedian lines weak and irregular; microtubercles oval .... *mori*
10. Featherclaws 6-rayed (About 8 or fewer markings on genital flap; microtubercles rounded and in center of annular rings) .... slykhuisi
10. Featherclaws 7-rayed 11
11. Shield without markings, narrowed anteriorly; microtubercles small, located on posterior margin of annular rings (on bermuda grass) .... *cynodonis*
11. Shield with median line incomplete, admedians complete, and submedians irregular; microtubercles of average size, located in posterior half of annular rings .... *tulipae*

Aceria parulmi (Keifer)
(Plate 3)

Aceria parulmi Keifer, 1965. Eriophyid studies B-13. Bureau of Entomology, California Dept. Agr., p. 9.
Type locality: Beloit, Wisconsin.
Type host: Ulmus americana L.

Relation to host: Fingerlike galls are produced on the upper leaf surfaces. This is also true for specimens collected in Kansas from the same host species. The Kansas material had galls of various sizes and mites were very numerous. Even when galls were abundant the host plant was not seriously injured. Galls on young leaves had the same green color as the leaves but on older leaves, galls were frequently brownish or dark in color. The number of galls varied from two to 25 or 30 per leaf. The infestation seemed localized on the host with only a few leaves in any single area showing galls.

Kansas record: Lawrence, Douglas Co., Kansas, Oct. 28, 1954, C. C. Hall (on the University of Kansas campus).

Aceria cactorum (Keifer)
(Plate 4)

Eriophyes cactorum Keifer, 1938, Bul. California Dept. Agr., 27:185.
Aceria cactorum (Keifer), Keifer, 1952, Bull. California Insect Survey, 2:25.
Type locality: Santa Paula, Ventura Co., California.
Type host: Opuntia sp.

Relation to host: No noticeable damage is reported to the host even though mites may be abundant on developing flowers and new pads. In Kansas this species is not abundant and specimens were difficult to find. The only records for this species are from Kansas and California.

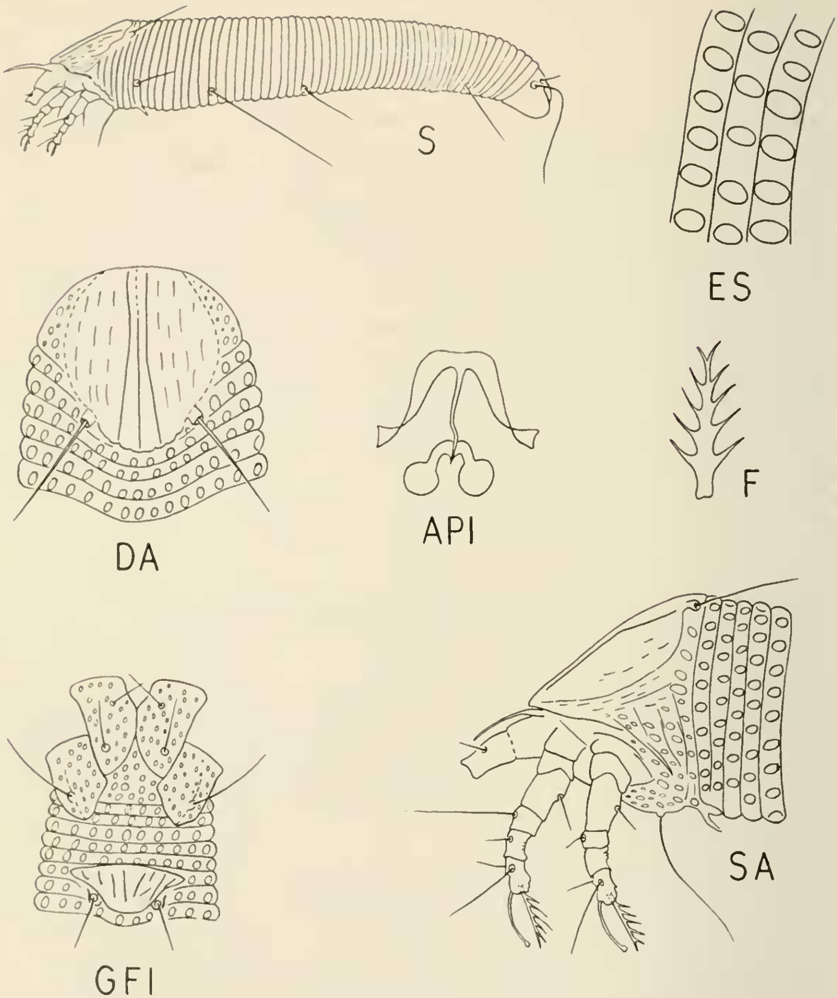
Kansas record: Lawrence, Douglas Co., Aug. 5, 1954, C. C. Hall (from *Opuntia* pads).

Aceria caryae (Keifer)
(Plate 5)

Eriophyes caryae Keifer, 1939, Bull. California Dept. Agr., 28:484.
Type locality: Brownwood, Texas.
Type host: Carya illinoensis (Wang), K. Koch, pecan.

Relation to host: A marginal leaf-roll on the upper surface is the type of damage produced by the species in all collected areas. These marginal deformities may be numerous or only a few present on a tree. The mites live in a large mass of spongy tissue produced inside the roll. Serious damage to pecan trees by this species has not been reported. This kind of injury was reported by Keifer (1939) for various *Carya* species.

Discussion: Aceria caryae and *Aceria erineus* (Nalepa) are very similar. The different hosts, walnut or hickory for *A. erineus* and pecan for *A. caryae*, indicate that these are perhaps good species. Morphological differences are chiefly seen in the shield, dorsal tubercles, and genital apodemes of the



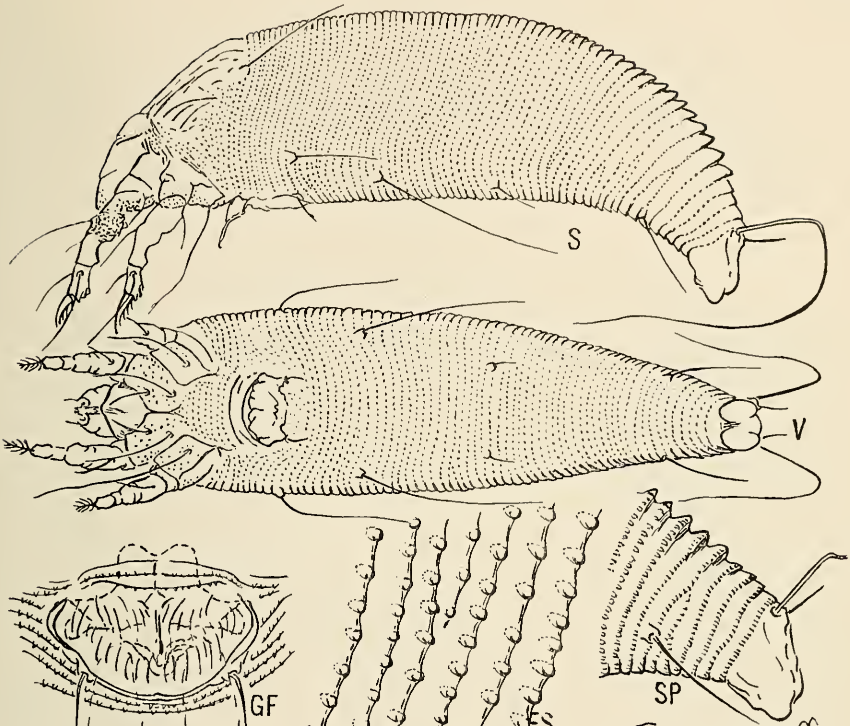
(Plate 3)

female. *A. caryae* also has body rings that are nearly smooth while the closely related species has microtubercles more distinct.

Kansas record: Baxter Springs, Cherokee Co., Oct. 9, 1954, C. C. Hall (from pecan).

Aceria celtis (Kendall)
(Plate 6)

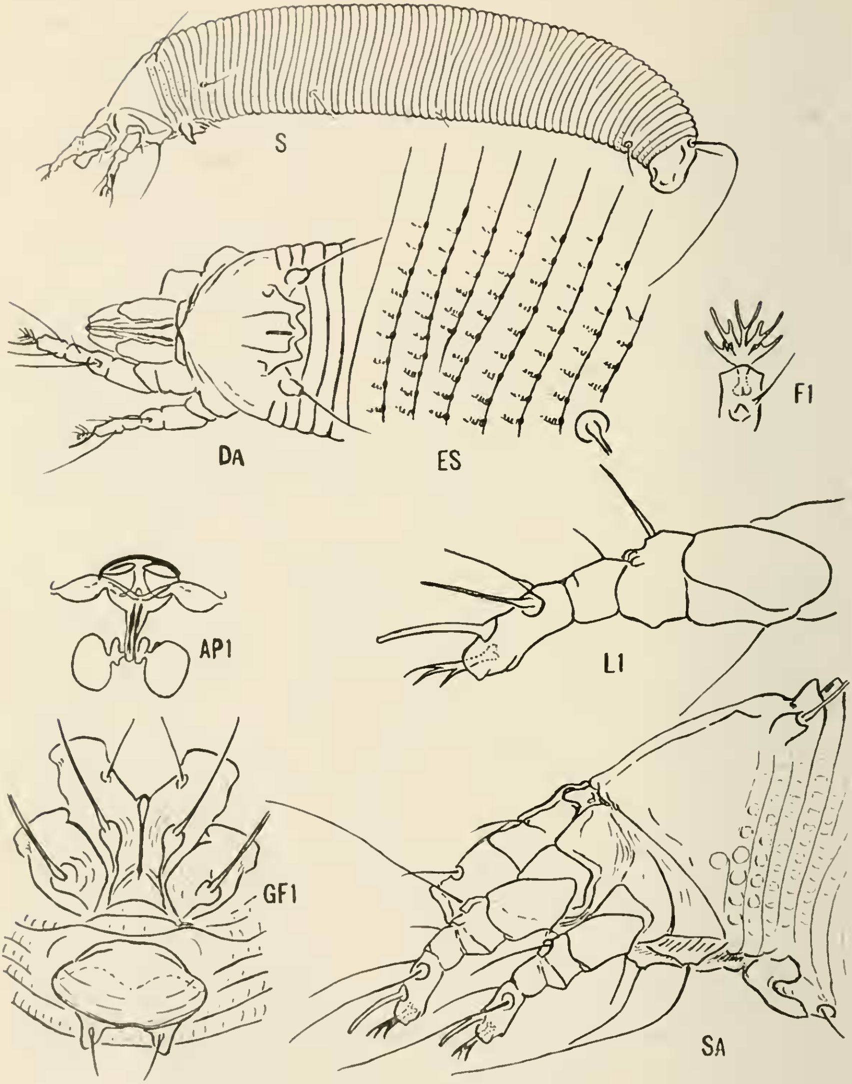
Eriophyes celtis Kendall, 1929, Psyche, 36:300.
Type locality: Forest Hills, Massachusetts.
Type host: *Celtis occidentalis* L., *Celtis occidentalis canina.*



(Plate 4)

Aceria snetsingeri Keifer, 1957, Bull. California Dept. Agr., 46:244 (new synonymy). *Type locality:* Bradley, Illinois. *Type host: Celtis occidentalis* L., hackberry.

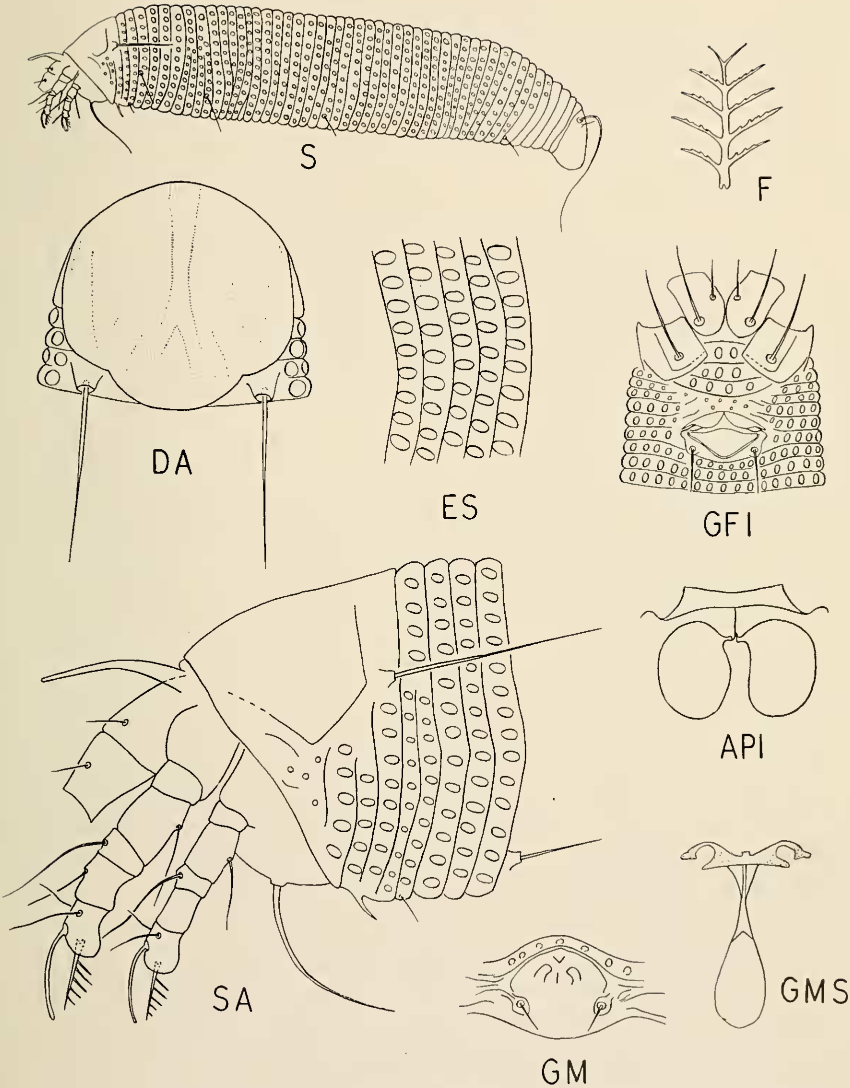
Relation to host: Bud deformation and "witches'-broom" development are the symptons shown by the host when infested with this species. Kendall



(Plate 5)

(1929) and Keifer (1957) report the type of damage mentioned above on the host plant. In Kansas the injury to the host is the same, and the photograph by Keifer (1957) could not be distinguished from a Kansas specimen. Mites may be taken from these "witches'-brooms" any time of the year.

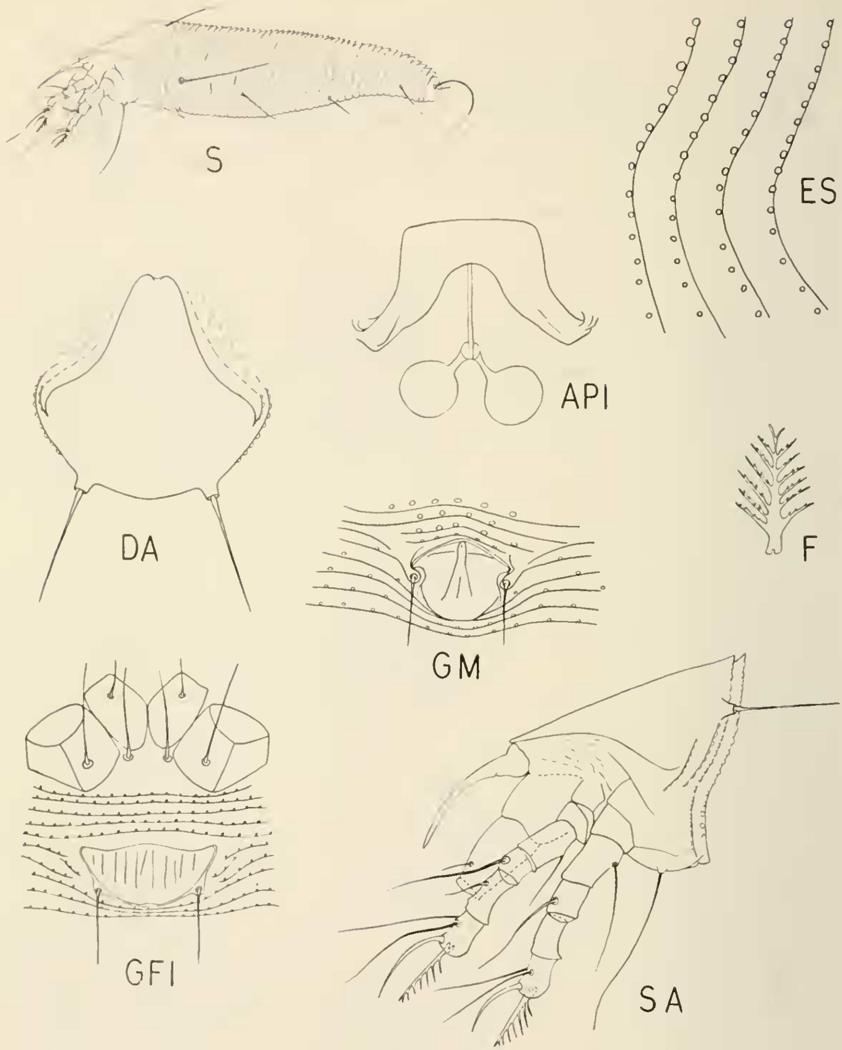
Discussion: This is apparently a widespread species following the range of its host. The writer has observed the typical damage throughout Kansas,



(Plate 6)

and it seems common also in Oklahoma and Texas. Specimens should be examined from the type locality and from several other areas to be sure this is a single species.

Kansas records: Lawrence, Douglas Co., Aug. 5, 1954, C. C. Hall (from hackberry "witches'-broom"); several samples of "witches'-brooms" from Riley Co. contained specimens of *Aceria celtis.*

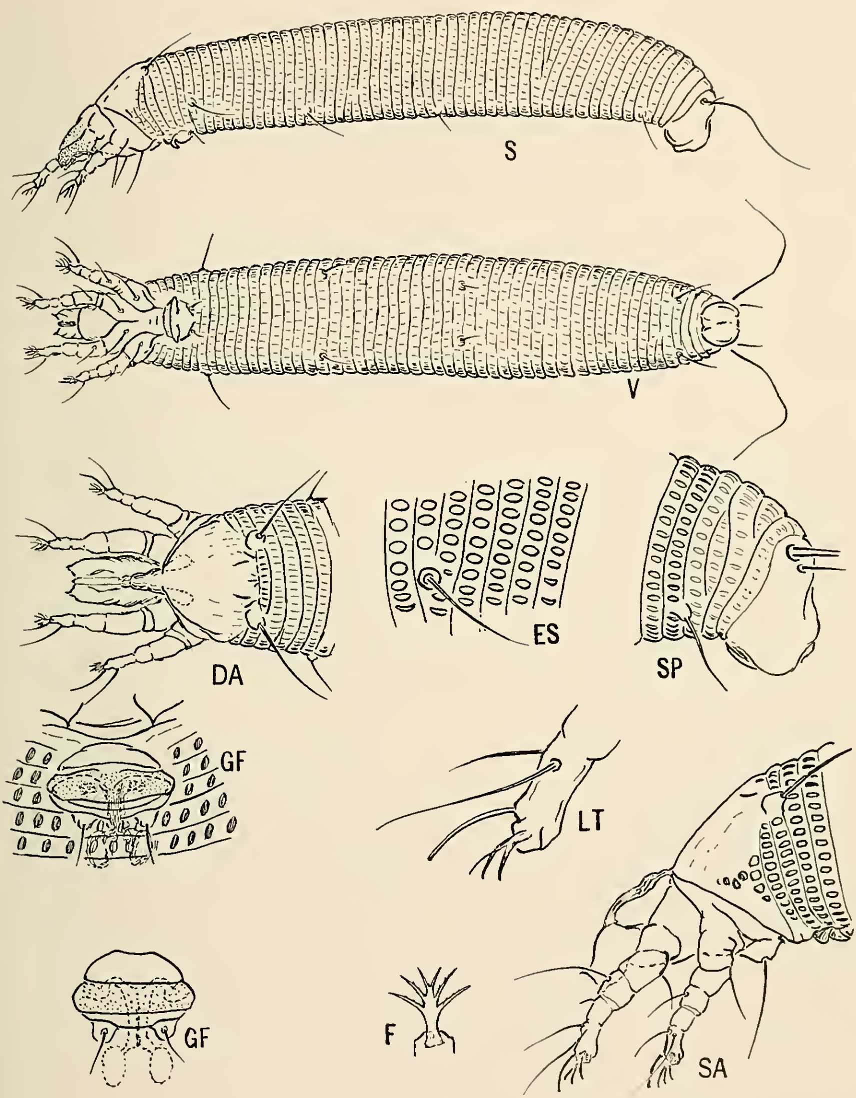


(Plate 7)

Aceria cynodonis Wilson
(Plate 7)

Aceria cynodonis Wilson, 1959, Ann. Ent. Soc. America, 52:142.
Type locality: Moreno, Riverside Co., California.
Type host: *Cynodon dactylon* (L.) Pers., bermuda grass.

Relation to host: Wilson (1959) describes the damage as mostly twisting of the folded terminal shoot with subsequent infolding and twisting of the expanded blade. Infested grass is easily recognized if it is allowed to grow



(Plate 8)

freely without cutting. The terminal loops formed by the weakened, distorted shoots are heavily infested with mites. This is similar to the condition exhibited by wheat that is infested with *Aceria tulipae*.

Discussion: There is no difficulty in separating this species from other *Aceria*. The shield design is characteristic and with the host reference *Aceria cynodonis* is quickly identified. Kansas material, kept in the greenhouse, developed a heavy infestation which caused some stunting of the grass. Some shoots formed five or six successive loops. All stages of development were present on the grass. Eggs were ovoid, transparent, and deposited in abundance in furrows on the inner surfaces of the leaves. Immatures were transparent to opaque. Larger, mature mites were darker in color but became no darker than a light brown. These mites were observed climbing plant hairs and extending their bodies into space with the posterior end of the mite attached to the plant hair; this was also done on the leaf surface. See behavior section for further discussion of this activity.

Kansas record: Manhattan, Riley Co., April 8, 1958, Salome del Rosario (from Bermuda grass).

Aceria erineus (Nalepa)
(Plate 8)

Phytoptus tristriatus erineus Nalepa, 1891, Anz. Akad. Wiss. math-nat. Wien, 28:162.
Aceria erineus (Nalepa), Keifer, 1952, Bull. California Insect Survey, 2:27.
Type locality: Austria?
Type host: *Juglans regia* L., Persian or English walnut.
Additional host: *Carya* sp., hickory, Franklin Co. Kansas.

Relation to host: The Kansas host material responds to the presence of this mite by producing a marginal leaf roll that is internally a mass of hairs in which the mites live. Damage to the host has been noted only as slight. On the type host, *Juglans regia* L., large masses of thick hair are produced on the lower surface of the leaf (Keifer, 1952).

Discussion: The most unique character of this species is the presence of genital tubercles. The shape of the genital coverflap is unusual. Actually this species seems close to *Aceria caryae* (Keifer) but has distinct microtubercles, a slightly different featherclaw, and no shield pattern. This is apparently another widely distributed species as indicated by its occurrence in Austria, California, and Kansas. Records are common in California and specimens are easily found on hickory in Kansas.

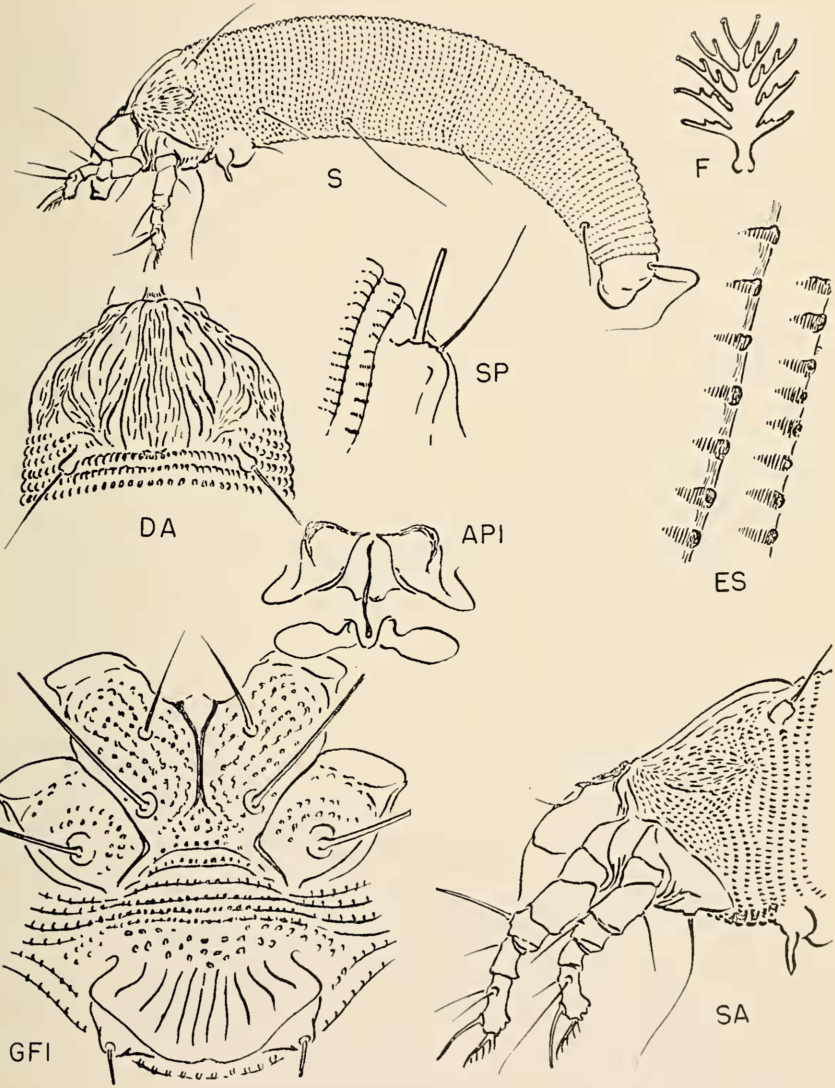
Kansas record: Franklin Co., May 14, 1954, C. D. Michener (from hickory).

Aceria lepidosparti Keifer
(Plate 9)

Aceria lepidosparti Keifer, 1951, Bull. California Dept. Agr., 40:95.
Type locality: San Bernardino (Devore district), San Bernardino Co., California.
Type host: *Lepidospartum squamatum* Gray.

Relation to host: On the type host, bud clusters are produced on the stems and stunting of growth occurs at that point. The Kansas host, *Morus rubra* L., did not show any abnormal growth except minor distortion of leaves.

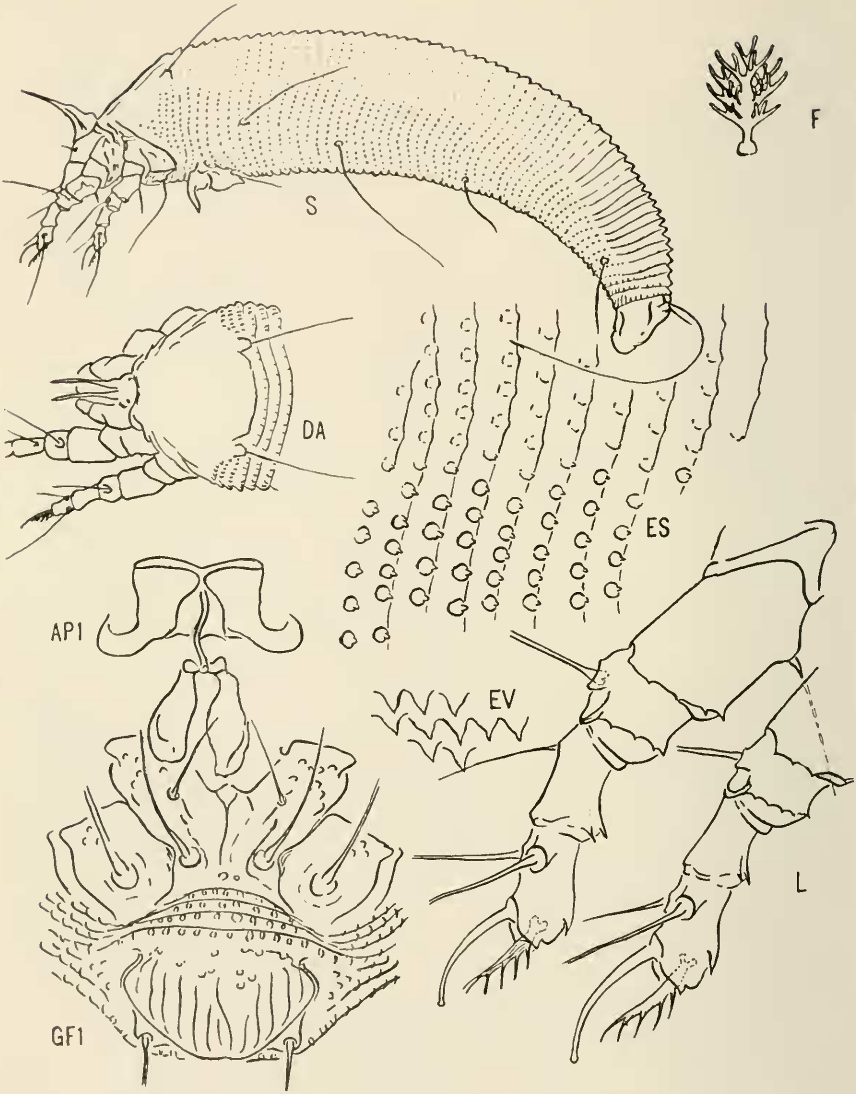
Discussion: A few specimens were obtained from Kansas material and, no morphological differences could be found between Kansas and California material even though hosts are greatly separated. Paucity of specimens and



(Plate 9)

excessive clearing in Hoyer's mounting medium have made the determination difficult. Specimens were examined carefully before excessive clearing took place and determined as *Aceria lepidosparti* or very near this species. The species has been collected only in Kansas and California.

Kansas records: Stafford Co., Aug. 14, 1955, C. C. Hall (on *Morus rubra* L., mulberry).

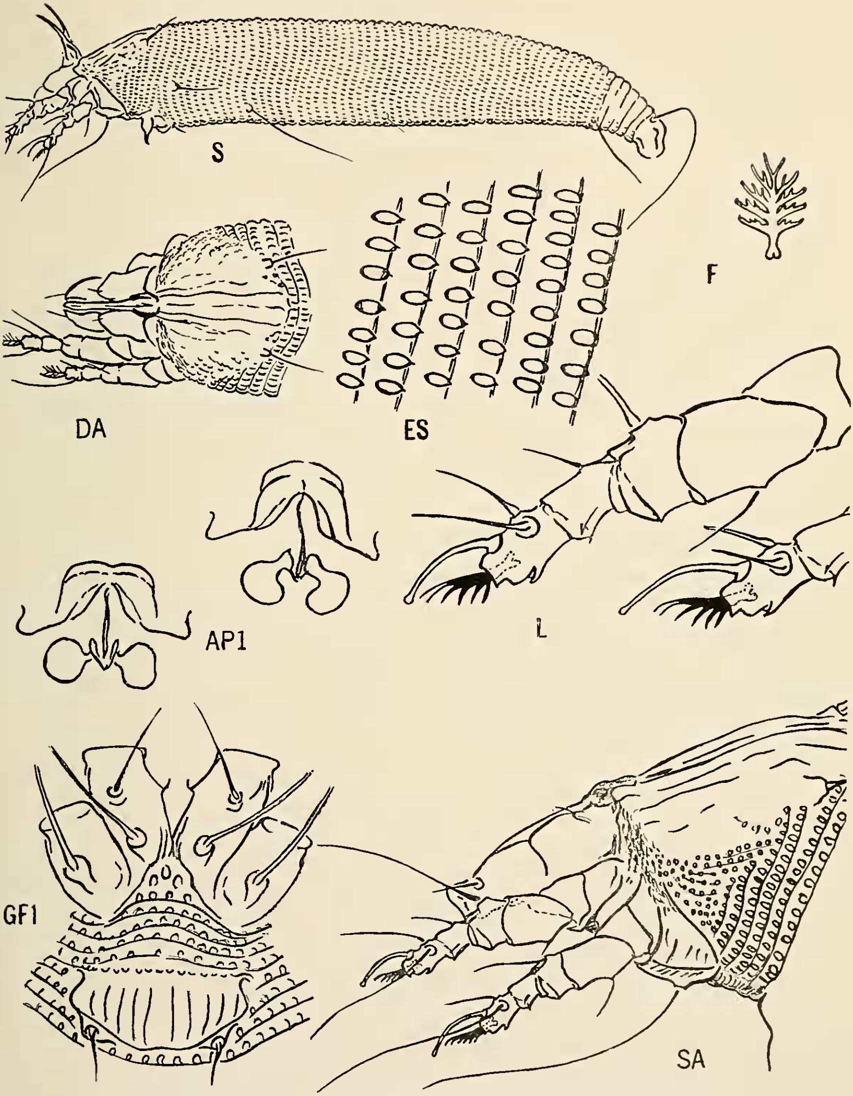


(Plate 10)

Aceria medicaginis (Keifer)
(Plate 10)

Eriophyes medicaginis Keifer, 1941, Bull. California Dept. Agr., 30:206.
Aceria medicaginis (Keifer), Keifer, 1952, Bull. California Insect Survey, 2:30.
Type locality: Sacramento, Sacramento Co., California.
Type host: *Medicago sativa* Linnaeus, alfalfa.

Relation to host: No damage has been reported from this species. Some-



(Plate 11)

times specimens are numerous but only slight growth deformity seems to result from this species. It is possible that it causes occasional flower damage but apparently not enough to consider it economically important. The mites live in the leaf axils and the buds.

Discussion: This is a typical *Aceria.* There is some suggestion of increase in the width of the tergites so that they are just slightly wider than the sternites. The lack of a shield pattern is also useful in identifying this species. *A. medicaginis* has been collected only in California and Kansas.

Kansas records: Marshall Co., Dec. 25, 1955, D. L. Matthew (from alfalfa): Hays, Ellis Co., Jan. 11, 1956, T. L. Harvey (from alfalfa).

Aceria mori (Keifer)
(Plate 11)

Eriophyes mori Keifer, 1939, Bull. California Dept. Agr., 28:485.
Aceria mori (Keifer), Keifer, 1952, Bull. California Insect Survey, 2:31.
Type locality: Sacramento, Sacramento Co., California.
Type host: *Morus* sp.
Additional host: *Morus* sp., Baxter Springs, Cherokee Co., Kansas. See relation to host and discussion.

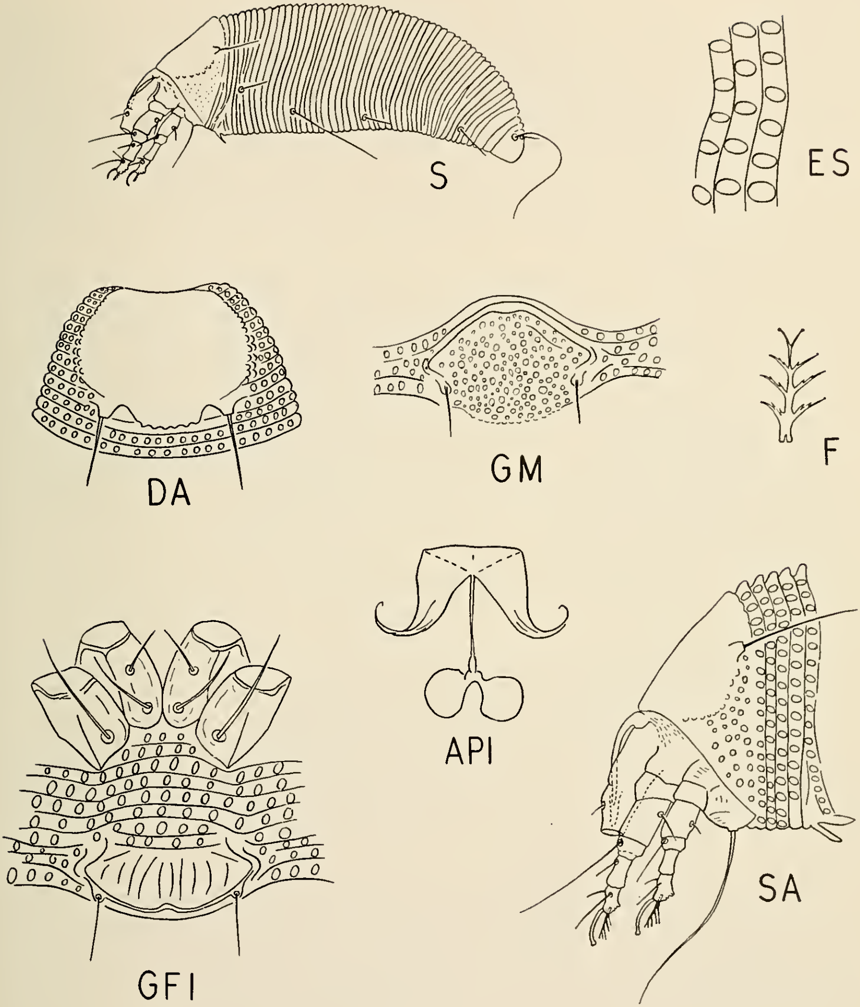
Relation to host: The California host shows some fruit deformity, but it is not certain that eriophyids are the cause. In Kansas the tree from which specimens were collected appeared to have lost all of its leaves, and new, distorted tufts of leaves were showing up, usually near the trunk. These tufts were infested with eriophyids, and occasionally mites could be found on the lower surface of some leaves.

Discussion: Similarities are striking between this species and other *Aceria*. *A. feijoae* (Keifer), *A. lepidosparti* Keifer, and *A. diospyri* Keifer can easily be confused with *A. mori*. The host, shield pattern, genital coverflap and microtubercles must be examined carefully to recognize this species. This species is known only from California and Kansas.

Kansas record: Baxter Springs, Cherokee Co., Oct. 9, 1954, C. C. Hall (from *Morus* sp.).

Aceria nimia, new species
(Plate 12)

Female: 167-170 μ long, 20 μ wide, wormlike, slightly arched in lateral view. Rostrum 22 μ long, straight, directed downward at slight angle to body. Chelicerae 15 μ long, curved evenly. Shield 21 μ long, 18 μ wide, without markings, rounded, posterior and lateral margins crenate. Dorsal setae 17 μ long, 18 μ apart. Dorsal tubercles projected from rear margin of shield. Forelegs 20 μ long; femur 7 μ long, seta 8 μ long; genu 5 μ long, seta 20 μ long; tibia 7 μ long, seta 6 μ long; tarsus 5 μ long, outside seta 18 μ long. Claw 8 μ long, curved, small knob at tip. Axis of featherclaw undivided, 4-rayed, shorter than claw. Hind legs 20 μ long; femur 7 μ long, seta 7 μ long; genu 4 μ long, seta 6 μ long; tibia 4 μ long, without a seta; tarsus 4 μ long, outside seta 18 μ long. Claw 8 μ long, curved, small knob at tip. Axis of featherclaw undivided, 4-rayed. Anterior coxae contiguous at posterior third; posterior coxae strongly emarginate, covering part of anterior coxae. Abdomen with 80 tergites and sternites. Microtubercles ovoid, papillose, centered in annular ring, similar in all areas, varying only in size. Female



(Plate 12)

genitalia 18 μ wide, 10 μ long, 9 or 10 longitudinal scorelines, setae 5 μ long. Apodemes strongly produced, spermathecae rounded.

Male: 130 μ long, similar to female. Genital coverflap papillose with slight indentation anteriorly.

Type locality: Lawrence, Douglas Co., Kansas, July 19, 1958, C. C. Hall, The University of Kansas campus in front of the library.

Type host: *Fraxinus americana* L. (Oleaceae).

Relation to host: Damage to the host is confined to the fruiting bodies which become rough, irregular, pendant masses of tissue. Mites are present in these distorted fruiting bodies.

Location of types: Female holotype and three paratype slides from the type locality bearing above data are deposited in Snow Entomological Museum, The University of Kansas, Lawrence. A paratype slide bearing the same data has been sent to H. H. Keifer, California Department of Agriculture, Sacramento, Calif. One paratype slide with the same data has been sent to the U.S. National Museum. Seven paratype slides collected May 21, 1954, C. C. Hall, from the same tree as well as dry paratype material are in the author's collection.

Discussion: The lack of figures and specimens for comparison make it difficult to give a statement regarding related species. Material sent to H. H. Keifer was considered by him to be new. Information gleaned from keys indicates that *Aceria fraxinivorous* (Nalepa) has a distinct shield pattern and the species described here has a shield without markings. The name of this species is formed from the Latin word *nimius* which means excessive and refers to the masses of distorted fruiting bodies produced by the host in response to the presence of this mite.

Aceria slykhuisi Hall
(Plate 13)

Aceria slykhuisi Hall, 1958, Jour. Kansas Ent. Soc., 31:233.
Type locality: Hays, Ellis Co., Kansas.
Type host: *Buchloe dactyloides* (Nutt.) Engelm., buffalo grass.

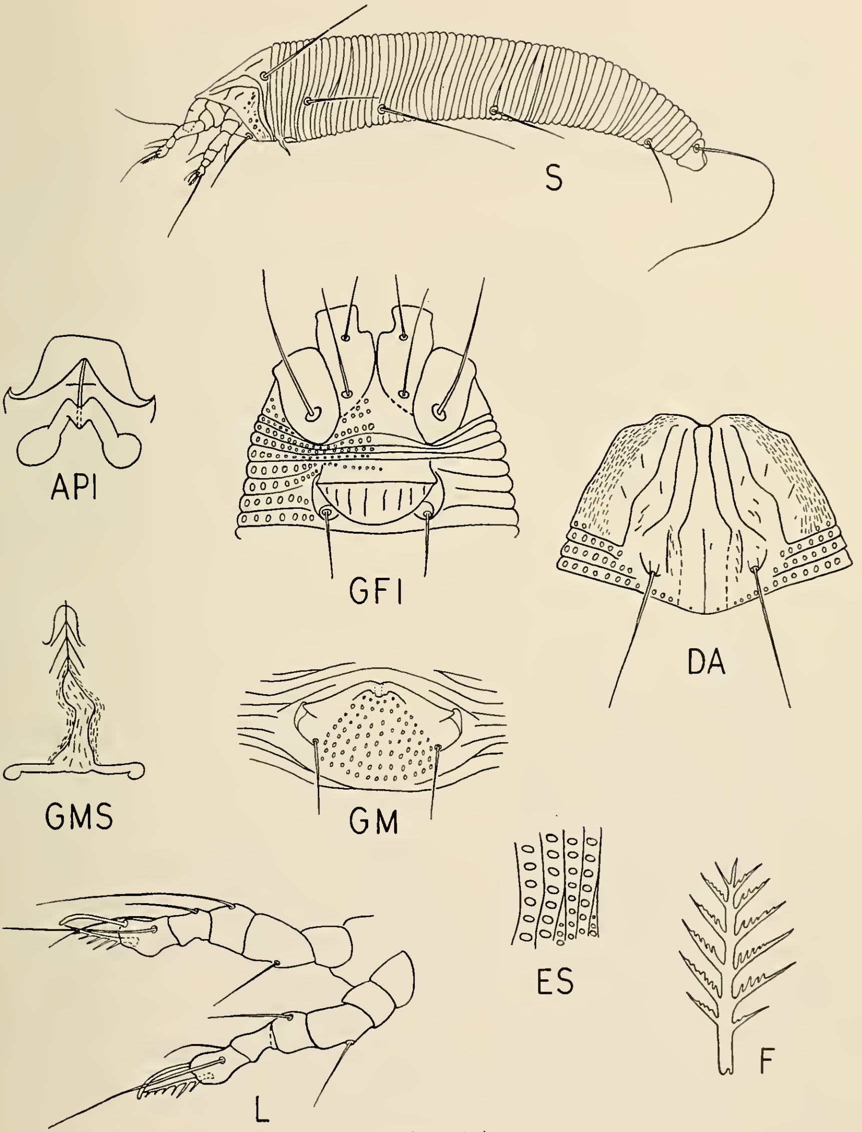
Relation to host: Witchbrooming seems to be caused by the presence of this mite on the pistillate plants. The presence of tarsonemid mites in these deformities is probably secondary since they appear later than the eriophyids. The relationship between tarsonemids and eriophyids is discussed by Hall (1958).

Discussion: This species is similar to *Aceria tulipae* but can be distinguished by the microtubercles, featherclaw, and genital coverflap. *A. slykhuisi* has been collected only from the type host, buffalo grass, and *A. tulipae* has been collected from several hosts. The host plant *Buchloe dactyloides* (Nutt.) Engelm. occurs throughout western Kansas where it is a dominant grass.

Kansas record: Hays, Ellis Co., Aug. 12, 1954, T. L. Harvey (from buffalo grass at Kansas Agr. Exp. Station).

Aceria tulipae (Keifer)
(Plate 14)

Eriophyes tulipae Keifer, 1938, Bull. California Dept. Agr., 27:185.
Aceria tulipae (Keifer), Keifer, 1952, Bull. California Insect Survey, 2:33.
Type locality: Sacramento, Sacramento Co., California.
Type host: *Tulipa* sp.
Additional hosts: *Allium cepa* L., *Allium sativa* L., *Agropyron smithii* Rydb., *Hordium jubatum* L., *Muhlenbergia racemosa* (Mich.) B.S.P., *Bromus maritimus* (Piper) Hitchc., *Bromus tectorum* L., *Digitaria sanguinalis* L., *Elymus canadensis* L., *Hordeum leporinum* Link., *Lolium*

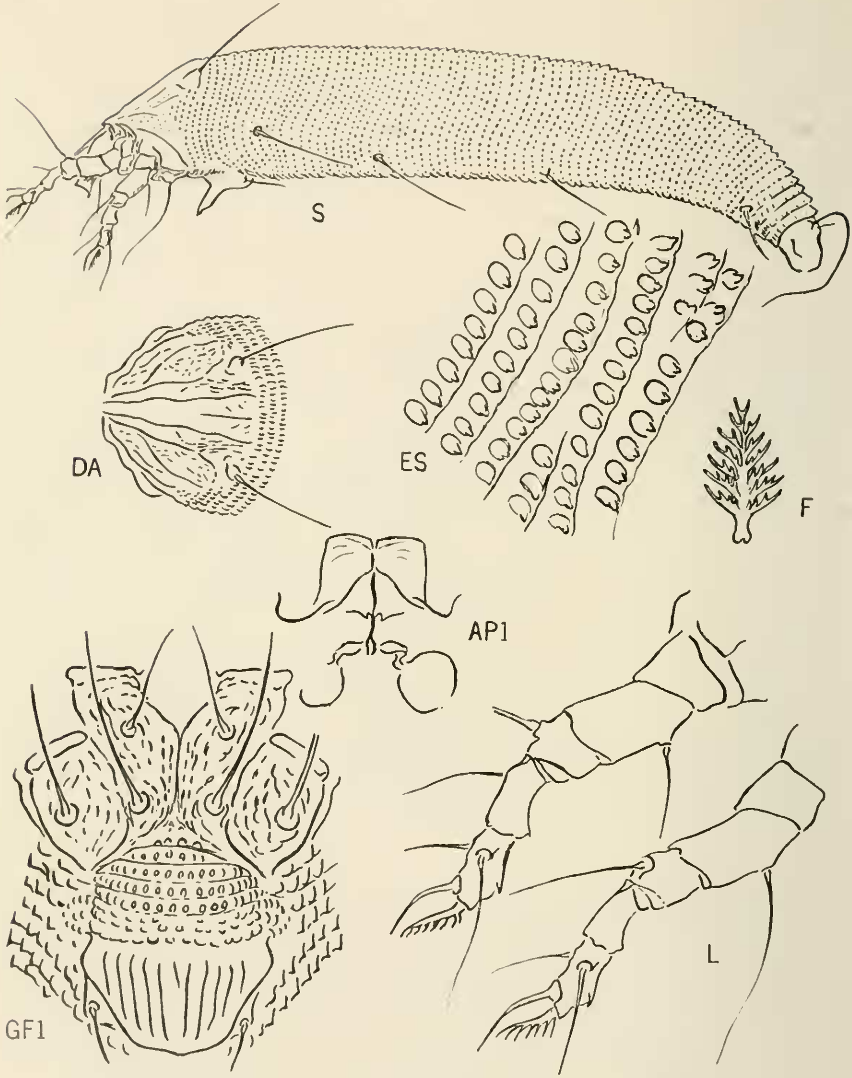


(Plate 13)

sp., *Setaria glauca* (L.) Beauv., *Setaria viridis* (L.) Beauv., and several varieties of wheat. Kansas records include onion, barley, wheat, and western wheatgrass.

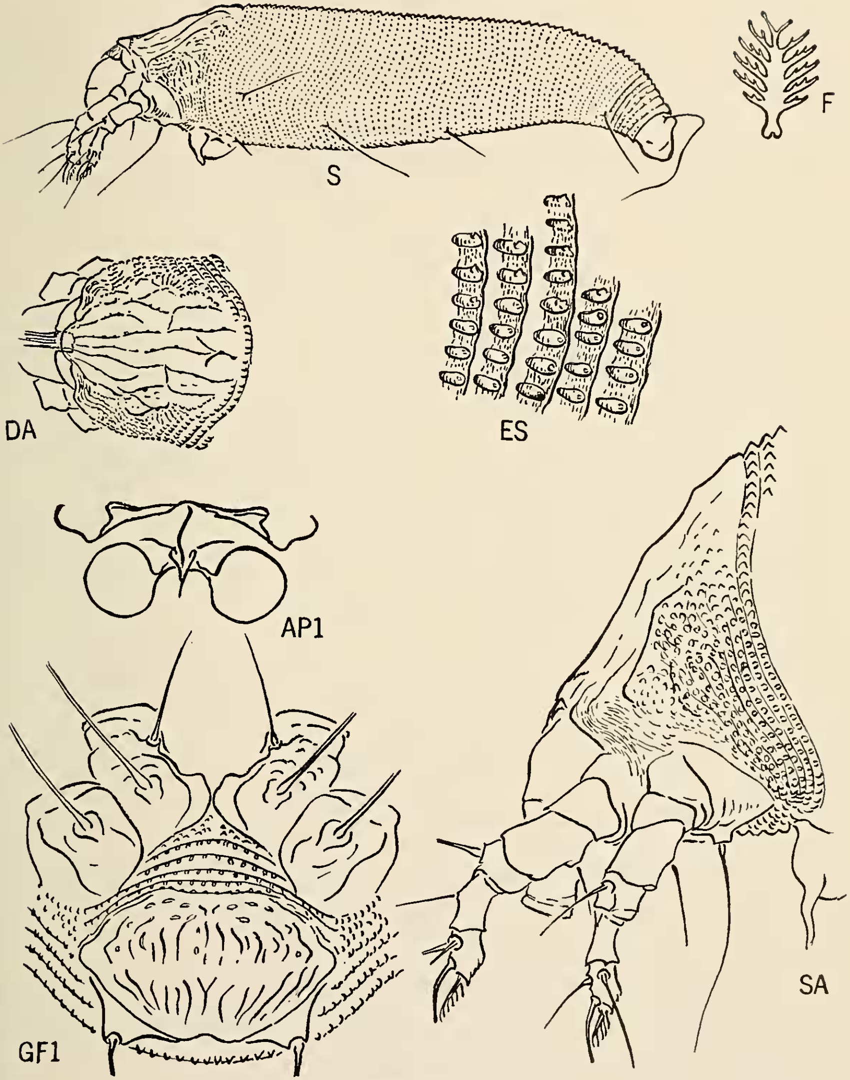
Relation to host: On most hosts of this species the "caught leaf" condition indicates the presence of mites.

Discussion: This species is the most important, economically, of all eriophyids since it serves as the vector of the wheat streak mosaic virus. *Aceria*



(Plate 14)

tulipae occurs throughout Kansas and is found in both North America and Europe. Keifer (1952) indicated common occurrence of this species on garlic imported from Mexico. Experiment stations are especially concerned with this economically important species, and useful information on biology and behavior can be gleaned from these reports and papers. *Aceria tulipae* still has not been thoroughly studied on all host plants and all host relationships are not clear.



(Plate 15)

Kansas records: Manhattan, Riley Co., March 7, 1954, R. E. Beer (wheat in greenhouse); Ottawa, Franklin Co., April 20, 1954, C. C. Hall (on volunteer wheat); Hays, Ellis Co., April 20, 1954, T. L. Harvey (from western wheatgrass); Lawrence, Douglas Co., May 11, 1954, C. C. Hall (wheat in the field); several field collections from Riley Co. and Ellis Co. Obviously this species occurs throughout the state, but it is more common in the western wheat fields.

Genus **Cecidophyopsis** Keifer

Cecidophyopsis Keifer, 1959, Bull. California Dept. Agr., 47:273.
Type of genus: Eriophyes vermiformis Nalepa, 1889 (by original designation).

Discussion: This is the only genus in the Eriophyidae that lacks the dorsal setae. The absence of shield setae, the genitalia close to coxae, the coxae slightly separated, and the coverflap with scorelines partly in two ranks are the more important characteristics of the genus.

This is a small but probably widespread genus with species in Oregon, California, Kansas, and several probable European species (Keifer 1959).

Cecidophyopsis hendersoni (Keifer)
(Plate 15)

"*Cecidophyes*" *hendersoni* Keifer, 1954, Bull. California Dept. Agr., 43:123.
Type locality: Syracuse, Hamilton Co., Kansas.
Type host: *Yucca glauca* Nutt., yucca.
Cecidophyopsis hendersoni Keifer, 1959, Bull. California Dept. Agr., 47:275.

Relation to host: A slight browning at the base of outer leaves where these mites live seems to be the only damage. This has been observed by Keifer (1954) and the writer. There is no extensive injury to the host.

Discussion: The possession of a 6-rayed featherclaw by *hendersoni* distinguishes it from *malpighianus* Nalepa, *psilaspis* Nalepa, *verilicis* Keifer, and *vermiformis* Nalepa which are all 5-rayed. Kansas and California are the only areas in which this species has been collected.

Kansas record: Syracuse, Hamilton Co., Aug. 14, 1955, C. C. Hall (from *Yucca glauca* Nutt.).

Genus **Eriophyes** von Siebold

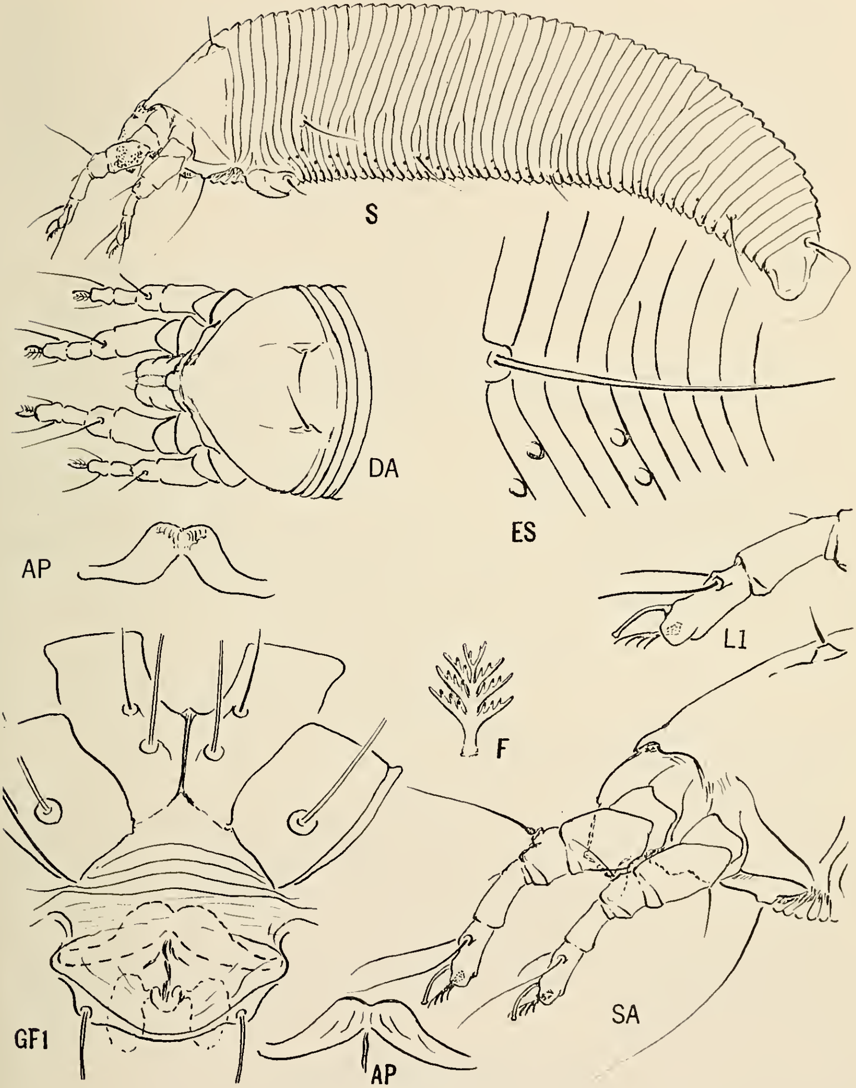
Eriophyes von Siebold, 1950, Jahresber. Schles. Ges., 28:89.
Type of genus: Eriophyes vitis (Pagenstecher), (by subsequent designation of Keifer, 1938, Bull. California Dept. Agr., 27:301).

Discussion: The genera *Aceria* and *Eriophyes* are somewhat similar. In *Aceria* the dorsal setae are located on the rear margin of the shield and directed caudally. Members of *Eriophyes* have the dorsal setae situated on tubercles slightly ahead of the rear margin of the shield and directed upward and forward or centrally.

Mites of this genus cause a variety of growth deformities. The common occurrence of gall and blister mites in this genus marks it as an economically important group. It is world-wide in distribution.

Eriophyes laevis (Nalepa)
(Plate 16)

Phytoptus laevis Nalepa, 1889, Sb. Akad. Wiss. Math-nat. Wien, 98:132.
Type locality: Austria.
Type host: Alnus glutinosa L.
Eriophyes laevis (Nalepa), 1898, Das. Tierreich, 4th Issue: Acarina, p. 7, Berlin. *Type locality:* Middle Europe (presumed locality). *Type host: Alnus glutinosa* L.
Eriophyes rhombifoliae Hassan, 1928, Univ. California Publ. Ent., 4:378. *Type locality:* Yosemite Valley, California. *Type host: Alnus rhombifolia* Nutt.
Eriophyes marinalni Keifer, 1939, Bull. California Dept. Agr., 28:223. *Type locality:* Stinson Beach, Marin Co., California. *Type host: Alnus oregona* Nutt., Red alder.



(Plate 16)

Eriophyes laevis (Nalepa) Keifer, 1952, Bull. California Insect Survey, 2:37. *Type locality:* Austria. *Type host: Alnus glutinosa* L., alder.

Additional hosts: Alnus oregona Nutt. and *Alnus tenuifolia* Nutt., both of California. *Betula pubescens* Ehrhart, *Alnus glutinosa* L., *Alnus incana* DC., and *Alnus pubescens* Tausch in Europe.

Relation to host: On the type host this species causes beadlike galls to form on the leaves. Small bead galls were also noted on *Salix* sp., the Kansas host. Damage to the Kansas host was very slight and only a few galls were collected. *Eriophyes laevis* and *Eriophyes emarginatae* Keifer are two distinct species that may be separated by examining the genital apodemes of the females. In *laevis* the genital apodeme is broad and short; *emarginatae* has an apodeme that is narrow and long. Austria, California, and Kansas are the only areas in which this species has been collected.

Kansas record: Baxter Springs, Cherokee Co., Oct. 9, 1954, C. C. Hall (from *Salix* sp.).

Genus **Oxypleurites** Nalepa

Oxypleurites Nalepa, 1891, Denk. Akad. Wiss. math-nat. Wien, 58:868.

Type of genus: Oxypleurites trouessarti (Nalepa), 1923, Verhandlungen Zool.-bot. Gesselschaft, Wien, 72:15.

Discussion: The most distinctive characteristic of this genus is the presence of lateral toothlike projections of the tergites. The tergites are much broader and less numerous than the sternites. The dorsal setae vary in position.

There are about 15 described species in this genus; most of them are from California and one species, *O. simus* Keifer, from North Carolina. There are a few European species indicating that this is another genus of wide range. It seems not to be of great economic importance; rusting, browning, and silvering of leaves are reported for various species.

Oxypleurites acidotus Keifer
(Plate 17)

Oxypleurites acidotus Keifer, 1939, Bull. California Dept. Agr., 28:493.

Type locality: San Francisco, California.

Type host: Baccharis pilularis DC., chaparral broom.

Relation to host: This is a vagrant species, chieflly on the upper surface of older, less viscid leaves on the type host. On *Morus*, the Kansas host, mites were taken from the lower surface of the leaf along veins and scattered. There were no deformities of foliage noted.

Discussion: In such a distinct genus with only a few species, comparison of genitalia separates species readily. Dorsal setae and tergites are also useful in determining species.

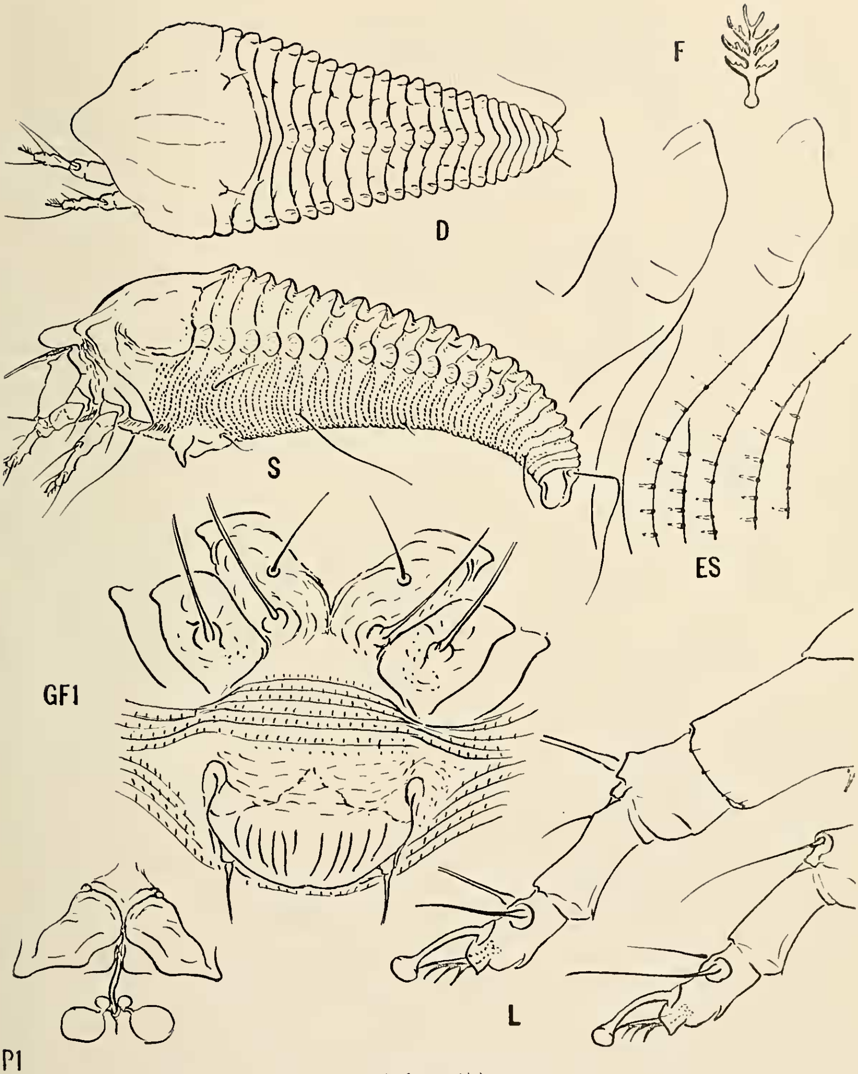
Genus **Phyllocoptes** Nalepa

Phyllocoptes Nalepa, 1889, Sitzb. Akad. Wiss. math-nat. Wien, 98:116.

Type of genus: Phyllocoptes carpini Nalepa (by subsequent designation of Keifer, 1938, Bull. California Dept. Agr., 27:191).

Discussion: This genus may be recognized by the undivided featherclaws; dorsal setae ahead of rear margin of shield, directed centrally, upward, or forward; and the presence of slight subdorsal furrows on the abdomen.

Many species in this genus are vagrant forms, living usually on the lower surfaces of leaves. Buds, petiole bases, and fruit are also reported as areas where the species may be found. This genus also has a wide range and many

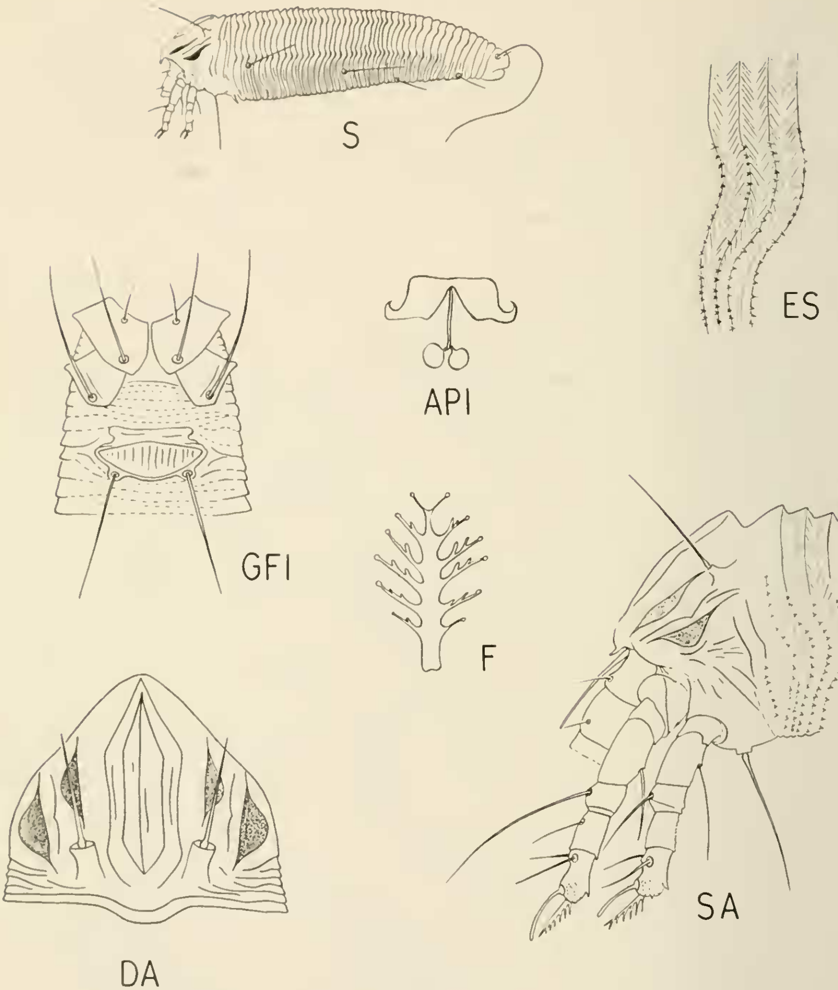


(Plate 17)

species. Nalepa described approximately 50 species from Austria, and Keifer has described several species from California.

Phyllocoptes microspinatus, new species
(Plate 18)

Female: 160 μ long, 38 μ wide, light brown in life, body tapering posteriorly to one-third anterior width. Body usually arched in lateral view.



(Plate 18)

Rostrum 25 μ long, straight, directed downward at slight angle. Chelicerae 15 μ long, practically straight. Shield subtriangular, overhanging rostrum with slight but distinct lip, 27 μ long, 28 μ wide; median line present but not extending entire length of shield; admedian lines present, meeting anteriorly and posteriorly with the median line; submedian lines meeting anteriorly and almost touching posteriorly. Each lateral surface of the shield with two cells somewhat darker than the surrounding area. Dorsal setae 23 μ long, directed anteriorly, usually converging slightly, 16 μ apart at base. Dorsal tubercles 5 μ long. Forelegs 31 μ long; femur 9 μ long, setae 35 μ long; genu 5 μ long, seta 25 μ long; tibia 7 μ long, seta 10 μ long; tarsus 9 μ long, setae

20 μ long. Claw slightly curved, 8 μ long, enlarged slightly at tip. Axis of featherclaw undivided and 6-rayed. Hind legs 28 μ long; femur 8 μ long, seta 15 μ long; genu 4 μ long, seta 15 μ long; tibia 6 μ long, lacking a seta; tarsus 7 μ long, setae 23 μ long. Claw 8 μ long, curved slightly, a little enlargement at the tip. Axis of featherclaw undivided and 6-rayed. Anterior coxae almost twice as large as the hind coxae, setae I and II equidistant from median line. Seta III more laterally placed than setae I and II. Tergites broader than sternites, 53 tergites present. Sternites smaller, microtuberculate with microtubercles present laterally but not on tergites. Microtubercles have very small spines and are located on the posterior margin of the annular ring. Abdomen with four longitudinal ridges, each ridge producing waxy plates and bearing a few spinulate microtubercles. Occasionaly a female specimen is seen which differs only in lacking the four longitudinal ridges and microtubercles; these females are probably deutogynes since they occur in the same population and have all the other characteristics of the species. Genitalia of female 20 μ wide, 12 μ long, about 12 longitudinal scorelines present. Internal apodeme broad, somewhat rectangular. Spermathecae indistinct but apparently round and smaller than usual.

Male: Unknown.

Type locality: Iola, Allen Co., Kansas, Oct. 10, 1954, C. C. Hall.
Type host: *Juglans nigra* L. (Juglandaceae).

Relation to host: Mites were taken from the lower surface of the leaf. There was no obvious damage to the host.

Location of types: Female holotype and two paratype slides so designated from the type locality are deposited in the Snow Entomological Museum, The University of Kansas, Lawrence, Kansas. One paratype slide bearing the same data is deposited in the U.S. National Museum.

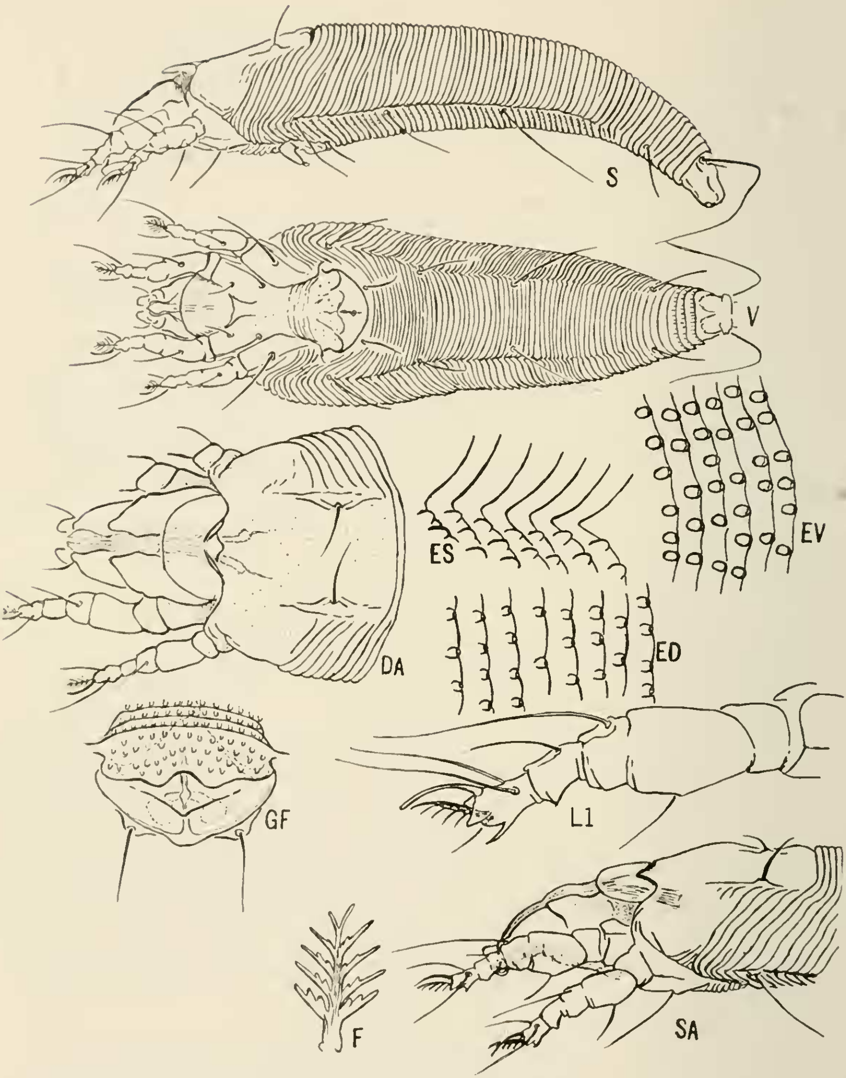
Discussion: This species is similar to *Phyllocoptes adalius* Keifer but is easily distinguished by the shield pattern and lateral markings on the shield of the new species. The posterior margin of the shield is more elevated in the new species than in *Phyllocoptes adalius* Keifer. This last condition is best seen in lateral view.

Genus **Platyphytoptus** Keifer

Platyphytoptus Keifer, 1938, Bull. California Dept. Agr., 27:188.
Type of genus: *Platyphytoptus sabinianae* Keifer, 1938, Bull. California Dept. Agr., 27:188 (by original designation).

Discussion: Mites of this genus can be recognized by the dorsoventrally flattened body with the abdomen subdivided by a sublateral groove into dorsal and ventral regions. The legs, setae, and featherclaws are not unusual.

Only a few species are described in this genus and all are from California. Material now in my collection indicates that at least one species, *Platyphytoptus sabinianae* occurs throughout the United States.



(Plate 19)

Platyphytoptus sabinianae Keifer
(Plate 19)

Platyphytoptus sabinianae Keifer, 1938, Bull. California Dept. Agr., 27:188.
Type locality: Oroville (Palermo), Butte Co., California.
Type host: *Pinus sabiniana* Douglas.
Additional hosts: *Pinus* spp., including *ponderosa* Douglas, *radiata* Don., *pinea* L., *Torreyana* Parry, *attenuata* Lemm., and *sylvestris* L.

Relation to host: Keifer (1952) states that mites of this species are usually found in needle sheaths living with *Trisetacus pini* (Nalepa) but in Kansas only *Platyphytoptus sabinianae* was found on the host. On another pine in Kansas, *Pinus nigra* Arnold, what appears to be *Trisetacus pini* lives in the absence of *Platyphytoptus sabinianae*. The presence of these mites does not seem to affect the host adversely.

Discussion: This is another example of a species that lives on several different hosts but all within a single genus. Keifer (1952) suggests that for this species to survive on a host, a well formed needle sheath is necessary for the protective niche.

Kansas record: Lawrence, Douglas Co., Sept. 22, 1958, C. C. Hall (from *Pinus sylvestris* L.). This same species was also taken from Christmas trees, *Pinus sylvestris* L., shipped to Kansas from Michigan.

Genus **Mesalox** Keifer

Mesalox Keifer, 1962, Eriophyid studies B-5. Bureau of Entomology, California Dept. Agr., p. 11.

Type of genus: Mesalox tuttlei Keifer.

Discussion: The most distinct characteristics of this genus are the dorsal longitudinal ridge system and the furrow between the ridges. Anteriorly the shield is shaped into a beaklike structure overhanging the rostrum; this is easily seen in lateral view. Divergent dorsal setae are set in dorsolateral tubercles and directed posteriorly. This genus is in the Phyllocoptinae of the Eriophyidae.

Mesalox tuttlei Keifer
(Plate 20)

Mesalox tuttlei Keifer, 1962, Eriophyid studies B-5. Bureau of Entomology, California Dept. Agr., p. 11.

Type locality: Bay City, Michigan.

Type host: Parthenocissus quinquefolia (L.) Planch. (Vitaceae) Virginia creeper.

Relation to host: On Virginia creeper the mites were undersurface leaf vagrants. In Kansas there was no apparent damage to the host (*Vitis* sp., grape) and mites were present on both leaf surfaces.

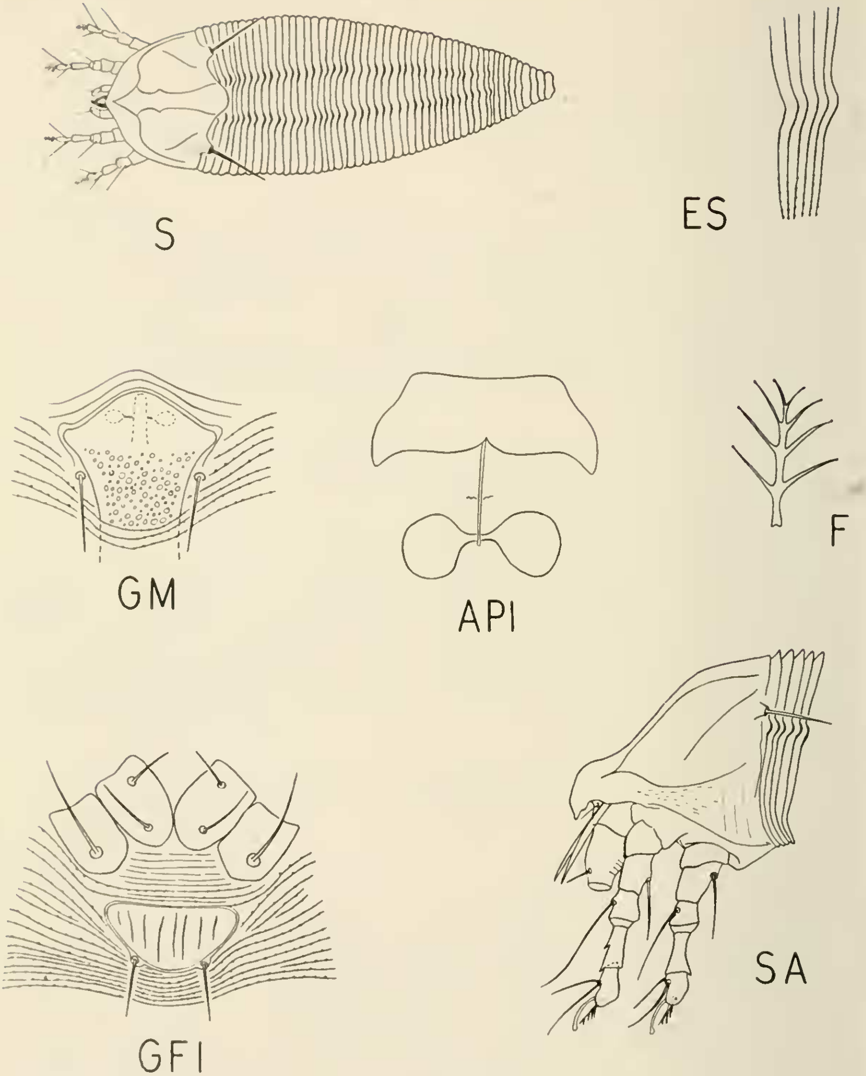
Kansas record: Baldwin, Douglas Co., Kansas, Aug. 11, 1955, C. C. Hall (from *Vitis* sp., Vitaceae, grape). Specimens were not abundant at this time.

Genus **Vasates** Shimer

Vasates Shimer, 1869, Trans. Amer. Ent. Soc., 2:319.

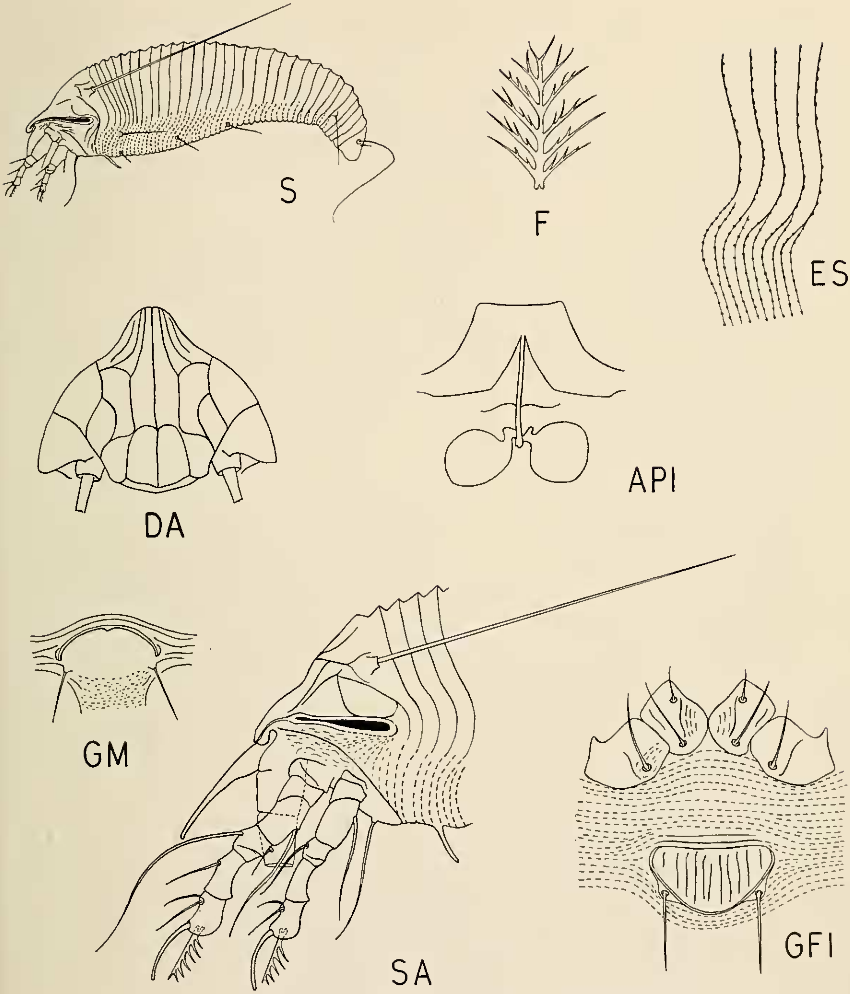
Type of genus: Vasates quadripedes Shimer (by subsequent designation of Keifer, 1944, Bull. California Dept. Agr., 33:25).

Discussion: This genus is characterized by a shield over the rostrum, dorsal tubercles on rear margin of shield, dorsal setae directed upward and caudally converging or diverging, and usually fewer tergites than sternites.



(Plate 20)

Most of the species in this genus are leaf vagrants, causing little or no abnormal growth. There are some exceptions. *V. quadripedes* is a gall-former on maple leaves and injury such as mottling or discoloration of leaves may result occasionally from the feeding of mites in this genus. There are many species that occur commonly in Europe and the United States.



(Plate 21)

Vasates cercidis, new species
(Plate 21)

Female: 170-184 μ long, about 50 μ wide, light brown color, arched strongly in lateral view. Rostrum 20 μ long, evenly curved downward. Chelicerae almost straight, 20 μ long. Shield 32 μ long, 45-55 μ wide, narrowed anteriorly, projected slightly over the rostrum, pattern of irregular cells, median and admedian lines complete, submedian lines present but irregular. Dorsal setae 100 μ long, on conspicuous tubercles, 23 μ apart at base. Forelegs 35 μ long; femur 10 μ long, seta 10 μ long; genu 5 μ long, seta 23 μ long; tibia 7 μ long, seta 6 μ long; tarsus 7 μ long, setae 20 μ long. Claw 8 μ long, curved, without knob at tip. Featherclaw of 6 rays, each ray with 1-3 subdivisions. Hind legs about 30 μ long; femur 10 μ long, seta 10 μ long; genu 5 μ long, seta 10 μ long; tibia 7 μ long, no seta present; tarsus 6 μ long, setae 20 μ long. Claw 8 μ long, curved, without knob at tip. Featherclaw 6-rayed with 1-3 subdivisions on each ray. Anterior coxae slightly contiguous posteriorly, two setae on each; posterior coxae contiguous with anterior coxae, each with a single seta. About 35 tergites and 75 sternites, posterior margins beset with round microtubercles which are more numerous ventrally. Genitalia of female 21 μ wide, coverflap with about eleven longitudinal scorelines. Spermathecae spherical, about 8 μ in diameter.

Male: 165 μ long, 50 μ wide. Genital coverflap 18 μ wide with a shallow median notch on anterior margin, setae 10 μ long.

Type locality: Douglas Co., Kansas, June 12, 1955, C. C. Hall, on University of Kansas campus in front of Snow Hall.
Type host: Cercis canadensis L. (Leguminosae).

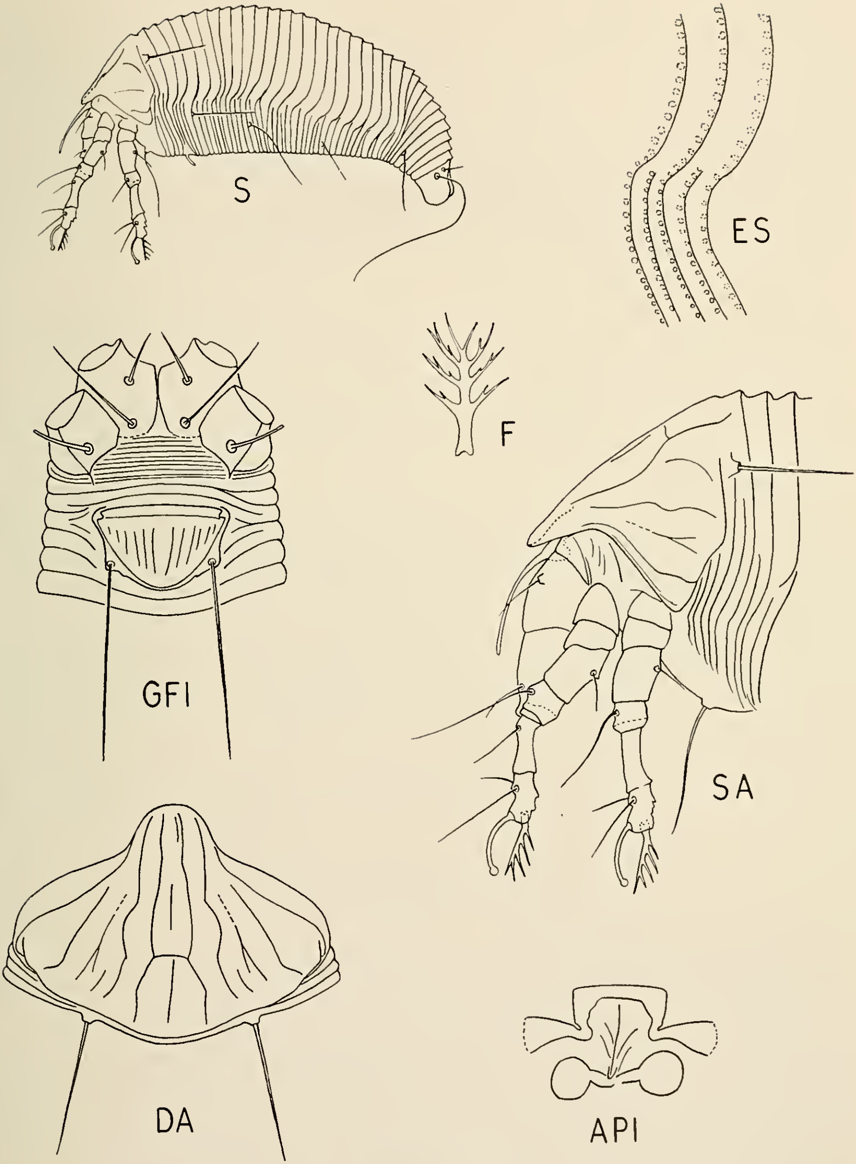
Relation to host: This is a free living species found chiefly on the lower surfaces of the leaves in late summer. For a more detailed account of this species, see the life history section. This species occurs commonly throughout Kansas wherever the host is found. There is no apparent damage to the host.

Location of types: Female holotype, male allotype, and five paratype slides all from the type locality are deposited in the Snow Entomological Museum, The University of Kansas, Lawrence, Kansas. One paratype slide with several specimens sent to the U.S. National Museum.

Discussion: This species is near *Vasates scotti* (Keifer) but can readily be distinguished by the dorsal setae being much shorter in *Vasates scotti*. The shape of the genital coverflap is also useful in separating these two species. In *Vasates cercidis*, the shield bears a lateral, dark, club-shaped mark that is not present in *V. scotti*. The name is formed from the generic name of the host plant.

Vasates dimidiatus, new species
(Plate 22)

Female: 200 μ long, 65 μ wide, dorsum strongly arched, sternites slightly arched in lateral view. Body color light tan in both adults and immatures. Rostrum 28 μ long, with even downward curve. Chelicerae 22 μ long, with slight curve, distal two-thirds of uniform size with slight enlargement at base. Shield 42 μ long, 55 μ wide, anterior lobe rounded and overhanging rostrum. Median line incomplete, admedian lines complete but undulating and diverging posteriorly, submedian lines irregular. Dorsal setae 24 μ long, directed posteriorly from rear shield margin, 35 μ apart, diverging slightly.



(Plate 22)

Dorsal tubercles distinct, about 3 μ long. Forelegs 39 μ long; femur 10 μ long, seta 15 μ long; genu 6 μ long, seta 30 μ long; tibia 12 μ long, seta 8 μ long; tarsus 9 μ long, seta 25 μ long. Claw 7 μ long, arched with knob at tip. Featherclaw 4-rayed with one or two subdivisions on each ray. Hind legs 38

μ long; femur 10 μ long, seta 13 μ long; genu 6 μ long, seta 10 μ long; tibia 9 μ long, lacking a seta; tarsus 8 μ long, seta 25 μ long. Claw 7 μ long, arched with small knob at tip. Featherclaw 4-rayed with small subdivisions. Anterior coxae touching in anterior, medial half. Posterior coxae widely separated, overlapping posterior margin of anterior coxae. All coxae with usual setae. Tergites much wider than sternites, 36 tergites and 72 sternites present. Sternites microtuberculate. Genital coverflap 10 μ long, 25 μ wide, bearing 12 longitudinal scorelines, setae 35 μ long.

Male: Unknown.

Type locality: Lawrence, Douglas Co., Kansas, May 25, 1958, C. C. Hall. Five miles north of Lawrence, Kansas.

Type host: Populus deltoides Marshall (Salicaceae).

Relation to host: There is very little damage to the host: however, the mites do occur more abundantly in marginally rolled leaves and on the lower surfaces of the leaves.

Location of types: A holotype slide and two paratype slides are deposited in Snow Entomological Museum, The University of Kansas, Lawrence, Kansas. Dry leaf samples bearing mummified specimens are in the author's collection.

Discussion: This species is morphologically very similar to *Vasates laevigatae* (Hassan) and *Vasates micheneri.* The genital coverflap and apodemes are the best characters to distinguish this species from *V. micheneri.* The shield pattern and genital coverflap separate this species from *V. laevigatae.* The name of this species is given because the annual rings are divided in half ventrally forming about twice as many sternites as tergites.

Vasates laevigatae (Hassan)
(Plate 23)

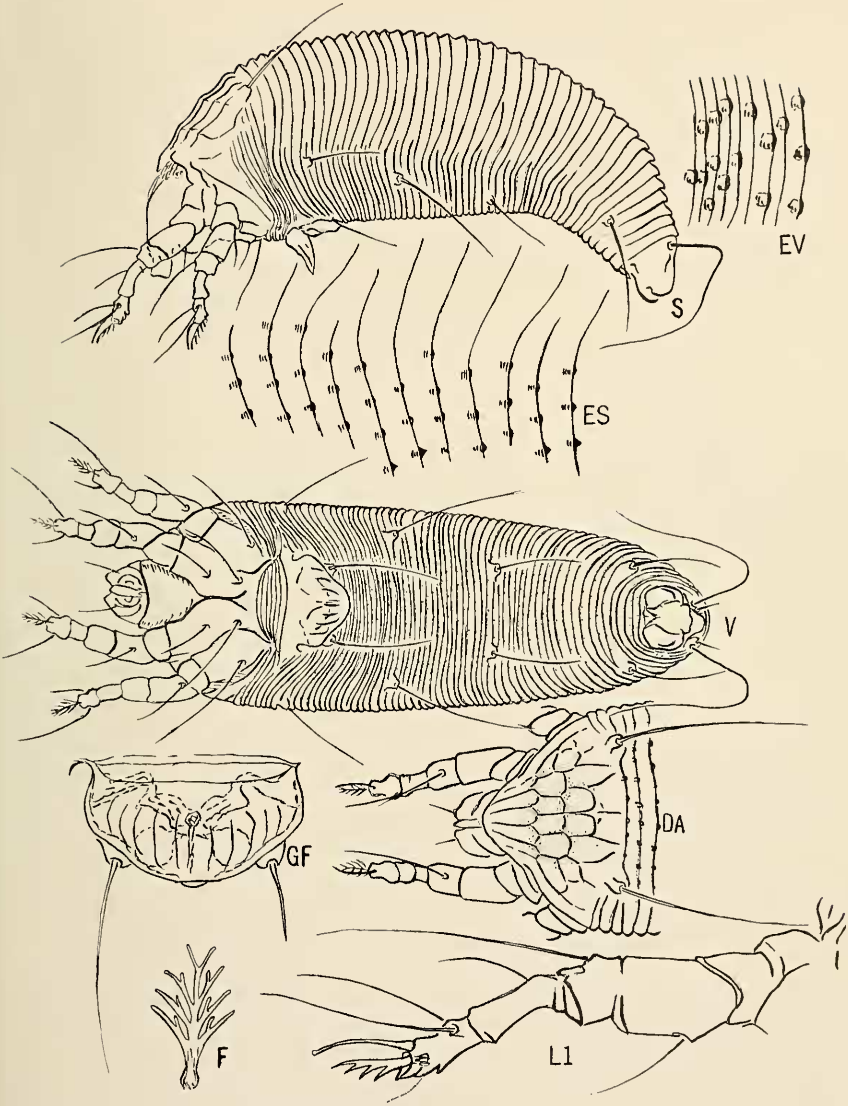
Phyllocoptes laevigatae Hassan, 1928, Univ. California Publ. Ent., 4:379.
Vasates laevigatae (Hassan), Keifer, 1952, Bull. California Insect Survey, 2:45.

Type locality: Agnew, Santa Clara Co., California.

Type host: Salix laevigatae Bebb, red willow.

Relation to host: Keifer reports the formation of beadlike galls on the host and indicates that these galls occur in colonies with some leaves showing many galls while other leaves have none. This same type of gall formation and distribution of galls is typical of this species in Kansas. Serious injury to the host has not been noted.

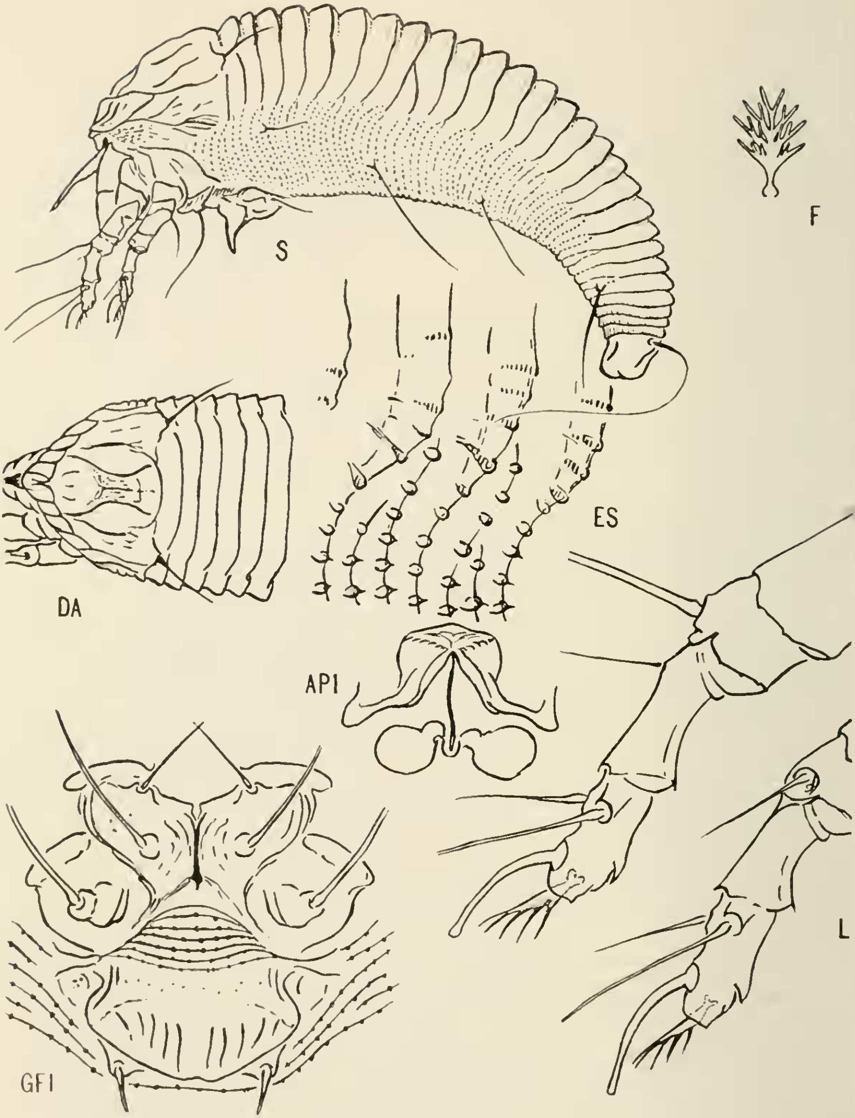
Discussion: Salix seems to serve as a host for several species of eriophyids. Those from willow are difficult taxonomically because some are probably deuterogynous; moreover, the species of willow are not easily determined so that aid from host relations is hard to obtain. These species of eriophyids will probably not be clearly understood until life histories are studied. *Vasates*



(Plate 23)

laevigatae and *Vasates micheneri* are similar species but the genital apodemes are very different; *V. laevigatae* has short, broad apodemes and those of *V. micheneri* are long and narrow.

Kansas record: Lawrence, Douglas Co., on U.S. hwy. 24-40 at east county line, Aug. 27, 1954, C. C. Hall (from *Salix* sp.).



(Plate 24)

Vasates lycopersici (Massee)
(Plate 24)

Phyllocoptes lycopersici Tryon, 1917 *(nomen nudum)*, Rept. Queensland Dept. Agr., p. 53.
Type locality: Australia.
Type host: Tomato.

Phyllocoptes lycopersici Massee, 1937, Bull. Ent. Res., 28:403. *Type locality:* Auckland, New Zealand. *Type host: Solanum lycopersicum* L., tomato.

Phyllocoptes destructor Keifer, 1940, Bull. California Dept. Agr., 29:160. *Type locality:* Modesto, Stanislaus Co., California. *Type host: Lycopersicum esculentum* Miller, tomato.
Vasates destructor (Keifer), Keifer, 1952, Bull. California Insect Survey, 2:44.
Vasates lycopersici (Massee), Lamb, 1953, Bull. Ent. Res., 44:347. *Type locality:* Auckland, New Zealand. Collected by W. Cottier. *Type host: Solanum lycopersicum* L., tomato. Type vial in East Malling Research Station collection, England.

Relation to host: Massee (1937) lists silvering, curling of leaves, leaf drop, blossom drop, and stunted fruits as injuries due to *Vasates lycopersici*. Keifer (1952) states that susceptible varieties of tomatoes are killed by this species. Injury to the host seems to be about the same in Australia, California, Kansas, and New Zealand. Massee did not include a figure in his description of *Phyllocoptes lycopersici*; however, the narrative account and host affinity indicate that *Vasates lycopersici* does occur on tomato in Australia, California, Kansas, and New Zealand. Lamb (1953) gives a complete account of eriophyids occurring on tomato.

Discussion: In his excellent revision of eriophyids occurring on tomato, Lamb (1953) includes convincing evidence supporting the synonymy of *V. destructor* and *P. lycopersici* with *V. lycopersici*.

Kansas record: Galena, Cherokee Co., Dec. 1958, L. A. Calkins (from tomato in greenhouse).

Vasates mckenziei Keifer
(Plate 25)

Vasates mckenziei Keifer, 1944, Bull. California Dept. Agr., 33:26.
Type locality: Sacramento, Sacramento Co., California.
Type host: Elymus triticoides Buckley, a perennial grass.
Additional hosts: Wheat, *Agropyron smithii* Rydb. (western wheatgrass), and *Distichlis spicata* L. (saltmarsh grass).

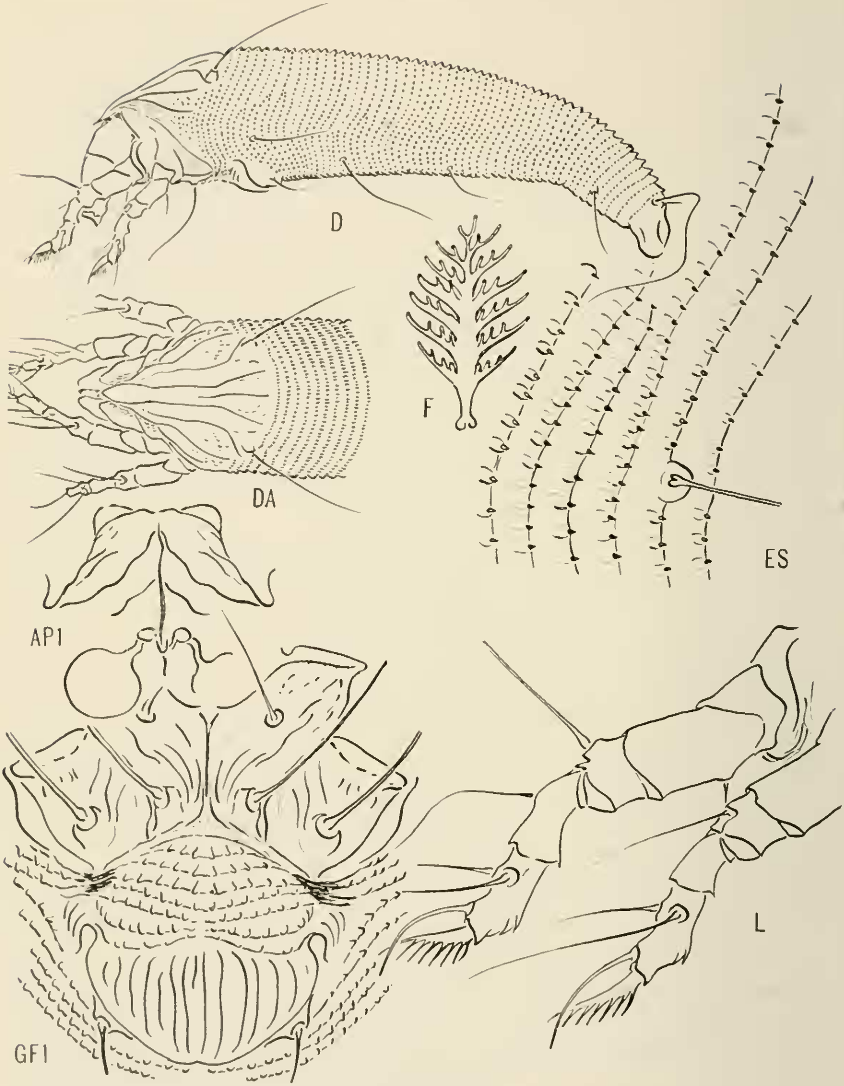
Relation to host: This species has not been reported to cause serious damage to hosts. This species becomes numerous in the furrows on the lower surface of the leaf. Keifer (1952) gives the longitudinal furrows on the upper surface of the leaf as the area in which the mites live on the type host. The occasional occurrence of this species on wheat warrants keeping it in mind as a possible carrier of wheat streak mosaic.

Discussion: In Kansas there is no difficulty in distinguishing this species from other *Vasates*. Keifer, however, indicates the possibility of confusing it with *Vasates dubius* Nalepa. I have not been able to obtain specimens or a drawing of *dubius* but Keifer has stated (correspondence) that one should watch for *dubius* as *mckenziei* is collected and studied.

Kansas records: Hays, Ellis Co., April 21, 1954, T. L. Harvey (from wheat); Hays, Ellis Co., May 7, 1954, T. L. Harvey (from *Agropyron smithii* Rydb., western wheatgrass); Haskell Co., May 17, 1958, J. F. Howell (from *Distichilis spicata* L., saltmarsh grass).

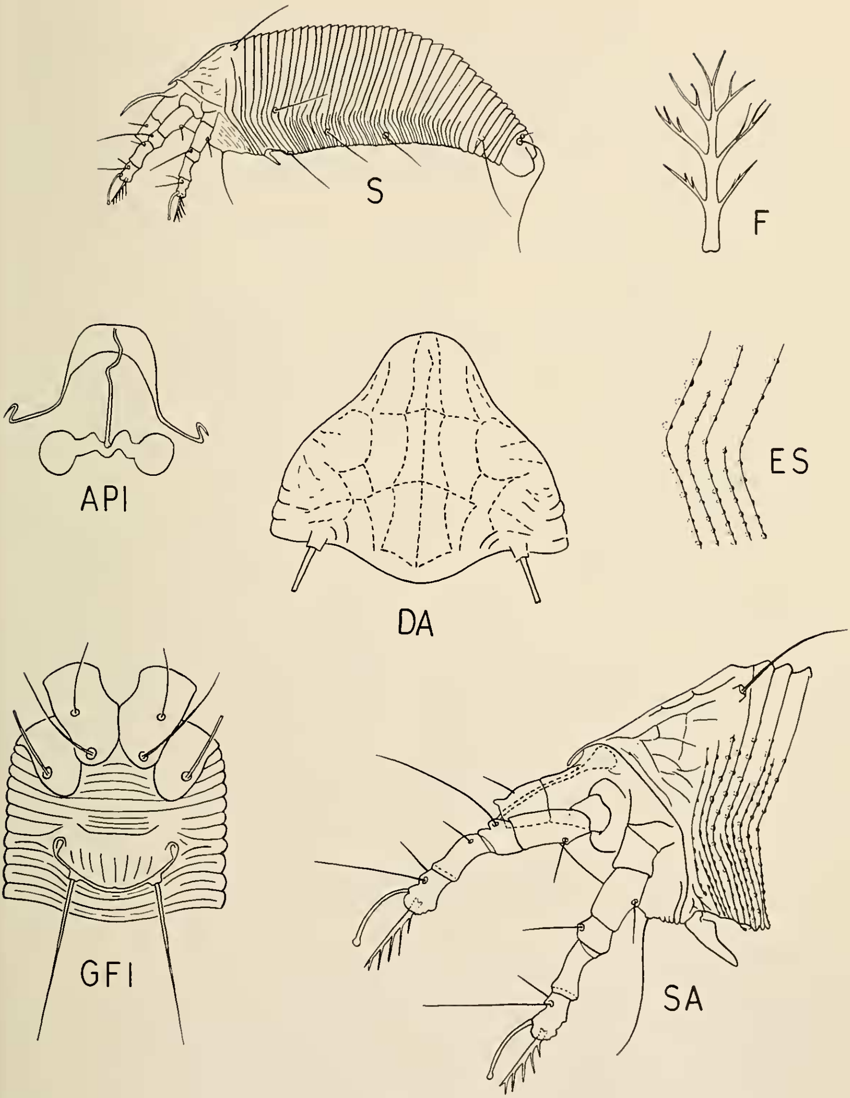
Vasates micheneri, new species
(Plate 26)

Female: 160-190 μ long, 48 μ wide, opaque white in life, slightly arch in lateral view. Rostrum 26 μ long, straight. Chelicerae evenly curved, 23 μ



(Plate 25)

long. Shield 26 μ long, 42 μ wide, subtriangular, extended slightly over the rostrum, rounded anteriorly in dorsal view, shield design weakly expressed consisting of six median cells bordered on each side by three lateral cells. Dorsal setae 33 μ long, directed posteriorly, diverging slightly, 27 μ apart at base. Dorsal tubercles distinct, located on posterior margin of shield. Forelegs 35 μ long; femur 12 μ long, seta 15 μ long; genu 7 μ long, seta 35 μ long;



(Plate 26)

tibia 10 μ long, seta 9 μ long; tarsus 8 μ long, seta 30 μ long. Claw 8 μ long, evenly curved, small knob at tip. Axis of the featherclaw undivided, 4-rayed with small subdivisions. Hind legs 35 μ long; femur 11 μ long, seta 14 μ long; genu 7 μ long, seta 18 μ long; tibia 8 μ long, seta absent; tarsus 8 μ long, seta 25 μ long. Claw 8 μ long, evenly curved, small knob at the tip. Axis of the featherclaw undivided, 4-rayed with subdivisions. Anterior coxae partly touching along medial margins. Posterior coxae contiguous with anterior coxae. Anterior and posterior coxae bearing usual setae. About 60 tergites present; sternites more numerous and microtuberculate. Microtubercles present ventrally and laterally, situated on posterior margin of annular ring. Genital coverflap of the female 20 μ wide, 10 μ long, 12-14 longitudinal scorelines present. Spermathecae 7 μ in diameter, round, connecting ducts about one-half the width of spermathecae.

Male: 218 μ long, 69 μ wide, similar to the female. Males were not common in occurrence.

Type locality: Lawrence, Douglas Co., Kansas, May 25, 1958, C. D. Michener.
Type host: *Salix nigra* Marshall (Salicaceae).

Relation to host: Mites were extremely abundant in distorted flower buds. The infestation had spread to nearly all areas of the tree. Eriophyids on willow are usually in small colonies and do not spread throughout even a single tree.

Location of types: A holotype slide and three paratype slides all from the type locality are deposited in the Snow Entomological Museum, The University of Kansas, Lawrence, Kansas. Dry plant material, containing paratypes is also in the author's collection.

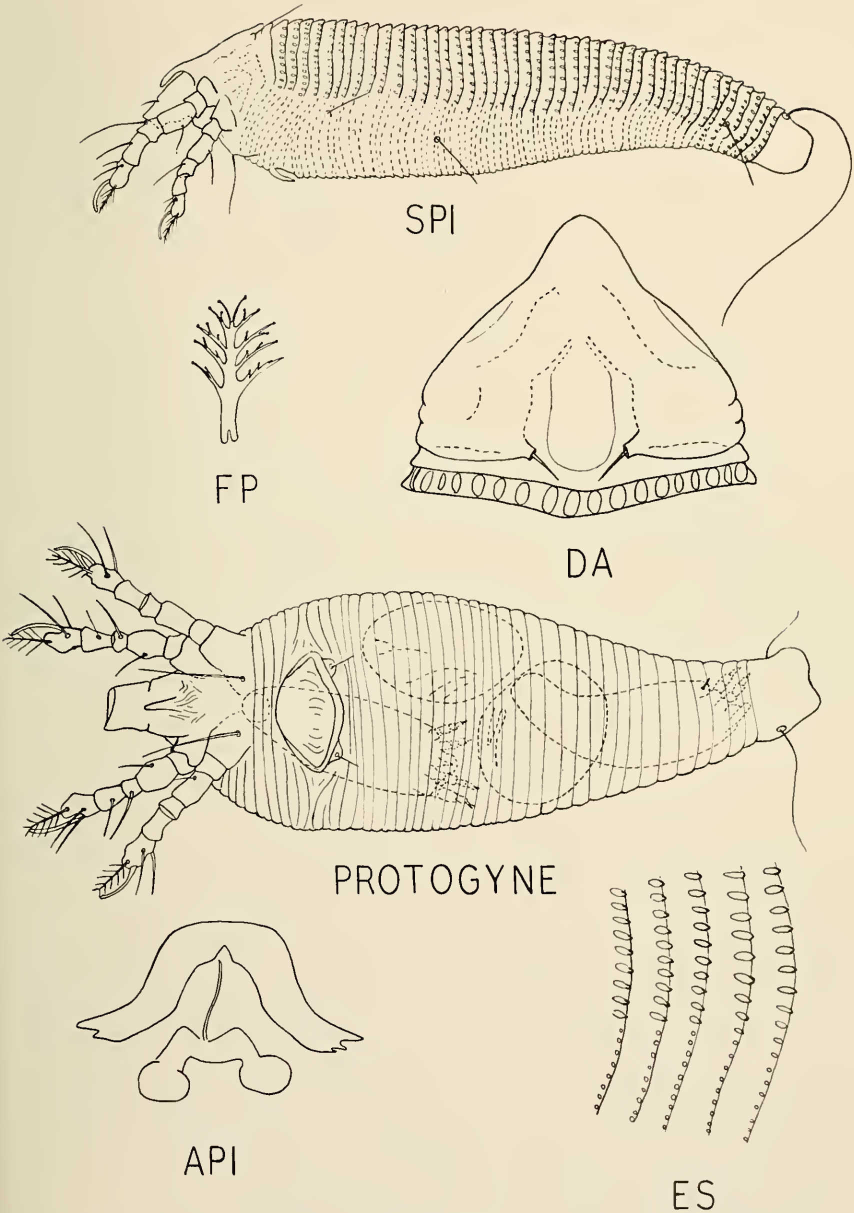
Discussion: This species is very similar to *Vasates rhodensis* Keifer and *Vasates laevigatae* (Hassan). The new species can, on the basis of a 4-rayed featherclaw and genital apodemes, be separated from the two closely related species. *Vasates micheneri* is probably deuterogynous. In some samples either two types of females or two species are present. Careful rearing and seasonal observations must be made to be sure about deuterogyny in this species.

Vasates quadripedes Shimer
(Plates 27, 28)

Vasates quadripedes Shimer, 1869, Trans. Amer. Ent. Soc., 2:319.
Phytoptus quadripes Osborn, 1879, Iowa College Quart., 2:32.
Eriophyes quadripes Banks, 1901, Amer. Econ. Ent., 7:106.
Phyllocoptes quadripes Parrot, Hodgkiss, Schoene, 1906, New York Agr. Exp. Sta. Bull., number 283.
Vasates quadripedes Shimer, Keifer, 1944, California Dept. of Agr. Bull., 33:25.

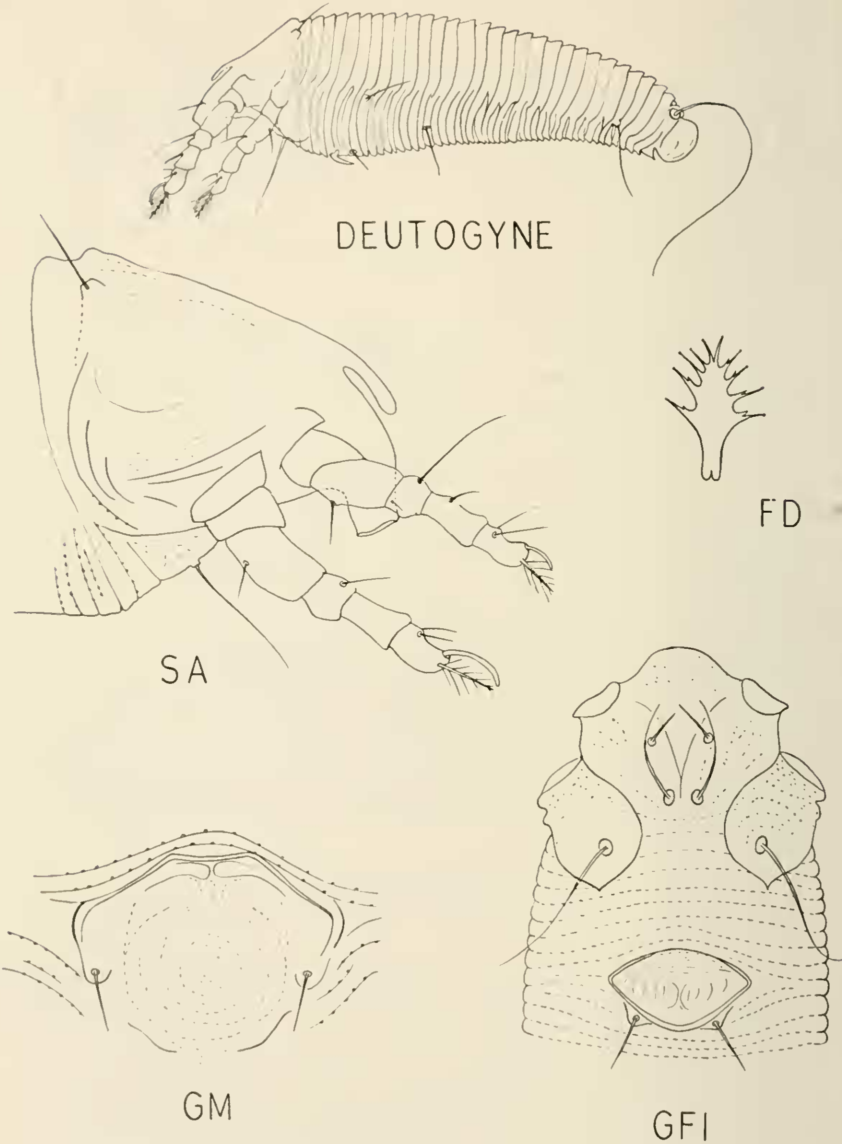
Since the original description and subsequent accounts of this species do not include species characteristics currently being used, they are included here for reference. Figures are also given to help distinguish between the protogyne and deutogyne. Males are noted and a sketch of the male genital coverflap is included.

Female: Protogyne 175-230 μ long, 60-70 μ wide, body round in cross section and wormlike, body pink in color but becoming more red in late summer. Shield 70 μ long, 70 μ wide, tapered anteriorly to a slight projection over the rostrum. Forelegs 42 μ long, all segments present, setae all present.



(Plate 27)

Hindlegs 42 μ long, all segments present, all setae present. Axis of featherclaw 5-rayed with small subdivisions present on some rays. Abdomen



(Plate 28)

composed of about 37 tergites and smaller more numerous sternites, microtubercles present. Genital coverflap with 8 to 10 longitudinal markings present.

Deutogyne 150-175 μ, similar to protogyne in appearance but lacking abdominal microtubercles and longitudinal markings on the genital coverflap. The featherclaw of the deutogyne also is more massive, especially the axis even though it bears the same number of rays.

Male: 110 μ long, 40 μ wide. In some galls males are very common in occurrence. It is not difficult to find males.

Type locality: Mt. Carroll, Illinois.
Type host: Acer dasycarpum, white maple.

Relation to host: The galls produced and resultant damage to the host are adequately described by Shimer (1869) and Hodgkiss (1930). Some of the affected foliage does drop to the ground, especially leaves that are entirely covered with these galls. Shimer (1869) indicates that a thousand or more galls may occur on a single leaf.

Discussion: In addition to the large number of galls produced by this species and resultant damage to the host plant there is an interesting problem concerning the life cycle.

Vasates quadripedes Shimer is undoubtedly deuterogynous. The two types of females and the males are almost always present in samples. I have observed eggs, larvae, and adults in abundance in galls. However, there is some evidence that this species can also be ovoviviparous. I have seen larvae hatched inside the body of the protogyne female (plate 27) and at least one other account of the ovoviviparous habit has been given by Shevtshenko (1961) in his observations on another species *Eriophyes laevis* (Nalepa). Sufficient data are not available now to say more about the ovoviviparous habit, but it does occur in two species of eriophyids.

PHYTOPTIDAE

Genus **Phytoptus** Djuardin

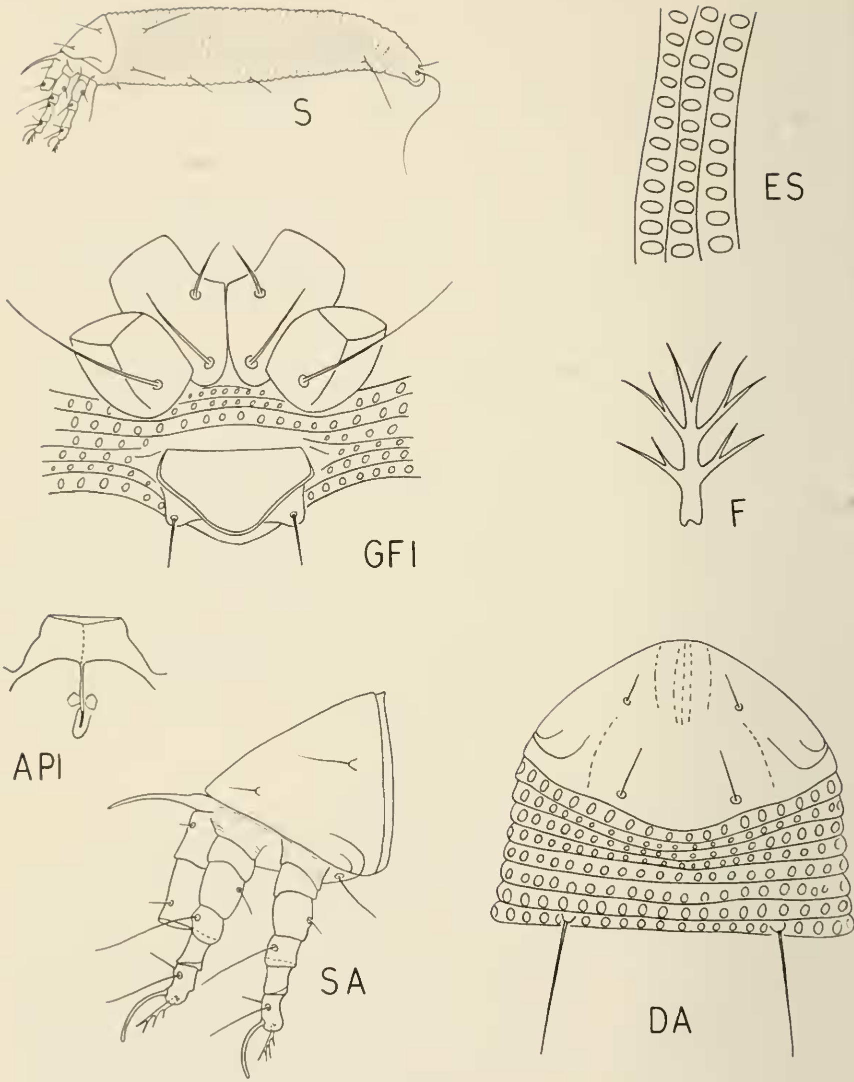
Phytoptus Djuardin, 1851, Ann. Sci. Nat., 15:166.
Type of genus: Phytoptus avellanae Nalepa (by subsequent designation of Keifer, 1938, Bull. California Dept. Agr., 27:301).

Discussion: Only a few genera are known that have four shield setae. Only one, *Phytoptus*, is wormlike, resembling the genus *Eriophyes*, and has subdorsal setae. The shield does not overhang the rostrum in the genus *Phytoptus* and the annular rings are similar above and below; the last seven or eight are wider, both dorsally and ventrally, than the preceding rings.

This genus is now represented by several species, most of which were described by Keifer and Nalepa, chiefly from Austria and the United States.

Phytoptus rotundus, new species
(Plate 29)

Female: 260 μ long, 65 μ wide, wormlike, very little arch to body in lateral view. Rostrum 20 μ long, straight. Chelicerae 15 μ long evenly curved. Shield 32 μ long, 55 μ wide; a few weakly expressed lines in the anterior,



(Plate 29)

central area. Dorsal setae 40 μ long, 20 μ apart at bases. Frontal setae 15 μ long, 18 μ apart at bases. Tubercles of dorsal and frontal setae smaller than average. Forelegs 32 μ long; femur 8 μ long, seta 10 μ long; genu 7 μ long, seta 25 μ long; tibia 7 μ long, seta 5 μ long; tarsus 9 μ long, seta 25 μ long. Claw 8 μ long, curved. Axis of featherclaw undivided, 3-rayed with some subdivision of rays. Hindlegs 32 μ long; femur 10 μ long, seta 10 μ long;

genu 5 μ long, seta 20 μ long; tibia 5 μ long, no seta present; tarsus 9 μ long, seta 25 μ long. Claw 8 μ long, curved, longer than featherclaw. Axis of featherclaw undivided, 3-rayed with some subdivision. Anterior coxae with median margins contiguous. Hind coxae appear to slightly overlay the anterior coxae. Tergites and sternites similar except the last seven or eight annular rings that are wider than the preceding rings. Abdomen bears subdorsal setae 45 μ long, lateral setae 20 μ long, first ventral setae 12 μ long, second ventral setae 11 μ long, third ventral setae 40 μ long, caudal setae, and accessory setae. Microtubercles in side view are ovoid and centrally placed in the annular ring. Genital coverflap of the female without markings, 20 μ wide, 10 μ long. Genital setae 8 μ long. Spermathecae not distinct. Two small dark bodies may be seen adjacent to the posterior extension from the genital apodeme; these are not in the normal position for spermathecae; it is not clear what these structures are.

Male: Similar to female, about 150 μ long.

Type locality: Franklin Co., Kansas, May 15, 1954, R. E. Beer.

Type host: Tilia americana L. (Tiliaceae).

Relation to host: Adult mites, eggs, and immatures were present in small irregular finger galls that occurred on both surfaces of the leaf. The galls were two or three mm in diameter and about four or five mm long. Their color was the same as that of the leaf and the apexes were truncate with several small papillae. Galls were common but other than these the host plant showed no damage.

Location of types: A holotype and five paratype slides bearing type locality data are deposited in Snow Entomological Museum, The University of Kansas, Lawrence, Kansas. One paratype slide with the same data is deposited in the U.S. National Museum. In addition dry paratype material is in the author's collection and dry paratype material has been sent to H. H. Keifer, California Department of Agriculture, Sacramento, California.

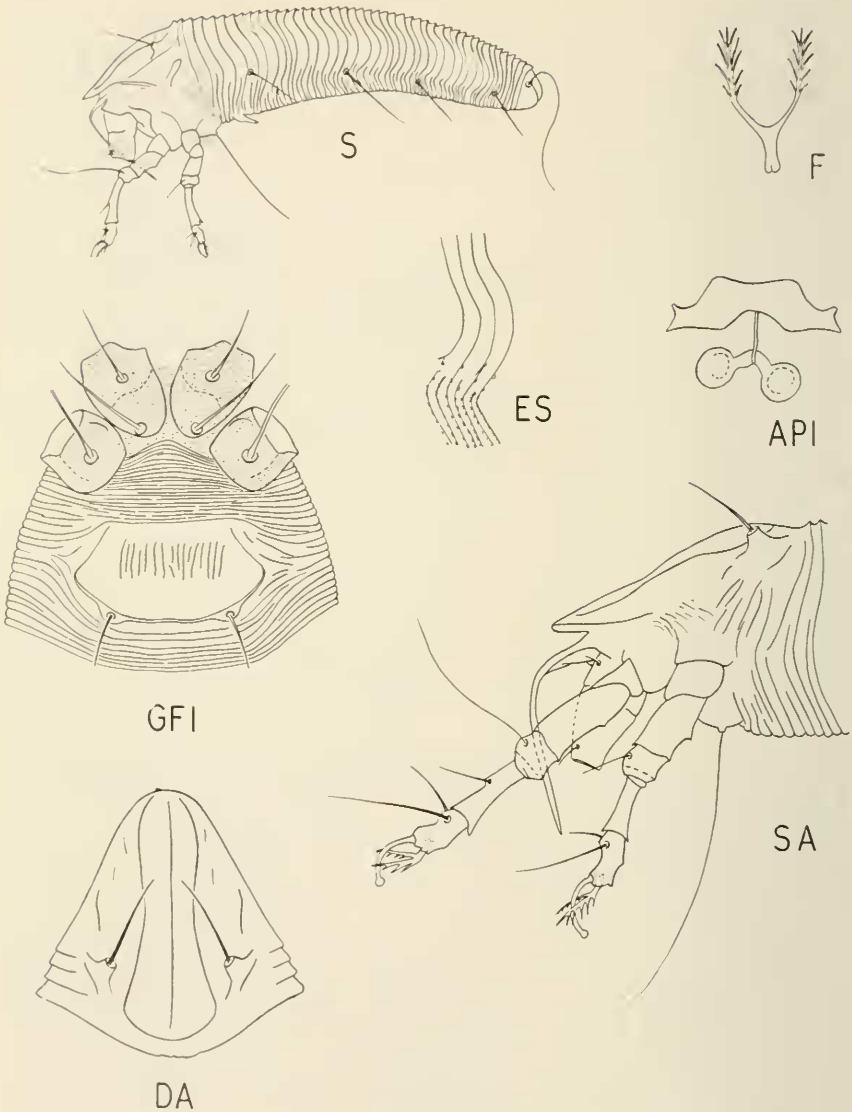
Discussion: Phytoptus rotundus is similar to *P. corniseminis* Keifer but can easily be distinguished by the 3-rayed featherclaw, which seems to distinguish *rotundus* also from other species of the genus. *P. abnormis* Garman is another species that should be noted here. The lack of figures and adequate description make it difficult to determine just what Garman had. The same host plant often does indicate the same species but this is not always true. More specimens are needed to clarify this question.

RHYNCAPHYTOPTIDAE

Genus **Apodiptacus** Keifer

Apodiptacus Keifer, 1960, Eriophyid studies B-1. Bureau of Entomology, California Dept. of Agr., p. 18.

Type of genus: Apodiptacus cordiformis Keifer, 1960, Eriophyid studies B-1. Bureau of Entomology, California Dept. Agr., p. 18.



(Plate 30)

Discussion: Members of the genus *Diptacus* are very similar to *A. cordiformis* K. but the presence of three dorsal longitudinal ridges in the latter easily separates the two genera. Both genera have species capable of producing white wax; in *A. cordiformis* K. white wax stripes are produced along the ridges.

Apodiptacus cordiformis Keifer
(Plate 30)

Apodiptacus cordiformis Keifer, 1960, Eriophyid studies B-1. Bureau of Entomology, California Dept. Agr., p. 18.
Type locality: West Hyattsville, Maryland.
Type host: Carya cordiformis (Wang.) K. (Juglandaceae), bitternut hickory.

Relation to host: No damage is noted to the host and mites are found as tiny tufts of white wax on the lower leaf surface. Material from Kansas had the same appearance.

Kansas record: Baldwin, Douglas Co., Kansas, Aug. 11, 1955, C. C. Hall. Specimens were taken from *Juglans nigra* L. (Juglandaceae) black walnut.

Genus **Rhyncaphytoptus** Keifer

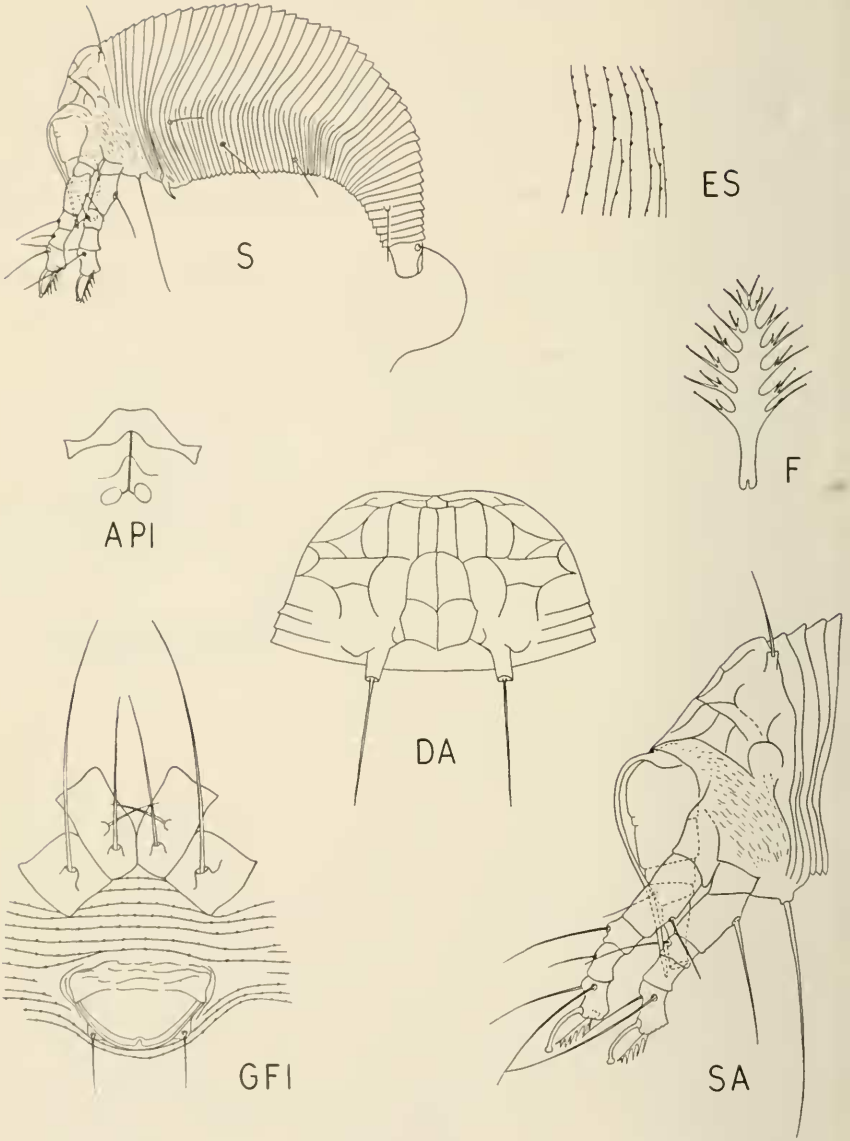
Rhyncaphytoptus Keifer, 1939, Bull. California Dept. Agr., 28:149.
Type of genus: Rhyncaphytoptus ficifoliae Keifer, 1939, Bull. California Dept. Agr., 28:150 (by original description).

Discussion: This genus is characterized by the large, abruptly bent rostrum and chelicerae. Sternites are more numerous than tergites and the axis of the featherclaw is undivided. The last mentioned character is most important and useful in distinguishing this genus from *Diptilomiopus* Nalepa which has a featherclaw with a divided axis.

Little is known about distribution; however, species are common in California and several European species have been reported.

Rhyncaphytoptus boczeki, new species
(Plate 31)

Female: 184-210 μ long, 70 μ wide, robust, semitransparent or very light brown color in life. Body strongly arched in lateral view; posterior third of body tapered somewhat abruptly. Rostrum 40 μ long, projecting down at slight angle. Chelicerae directed anteriorly basally, then strongly bent down, distal fourth slightly recurved. Shield 34 μ long, declivous anteriorly, 55 μ wide. Shield design of irregular cells, 6 cells adjoining median line. Laterally shield appears to have several pronounced ridges that sometimes form cells. Dorsal setae 25 μ long, on tubercles, 17 μ apart at base; directed upward. See lateral view to determine position of dorsal setae. Dorsal tubercles 7-8 μ long, slightly ahead of rear margin of shield, but long enough to extend beyond the posterior shield margin. Forelegs 43 μ long; femur 15 μ long with seta 9 μ long; tarsus 10 μ long, two setae 30 μ long; claw 9 μ long, slightly curved, small knob at tip; axis of featherclaw undivided, 7-rayed, each ray bearing small subbranches. Hind legs 38 μ long; femur 15 μ long on longest side, angular at base, femoral seta 15 μ long; genu 6 μ long bearing a seta 15 μ long; tibia 8 μ long without a seta; tarsus 10 μ long, two setae 30 μ long; claw 9 μ long, curved, small knob at tip; axis of featherclaw undivided with



(Plate 31)

7 rays, rays showing some subdivision. Anterior coxae about twice as long as wide, each coxa bearing two setae, posterior pair of setae about two times length of anterior pair of setae. Posterior coxae almost square, each coxa with a large seta 45 μ long. About 66 tergites; sternites closer together and more

numerous. Microtubercles on rear ring margins, varying from small dots to slightly larger triangles pointed posteriorly. Female genitalia 24 μ wide, setae 10 μ long; spermathecae about 5 μ in diameter, almost round; coverflap with a few basal transverse markings.

Male: Unknown.

Type locality: Kansas City, Wyandotte Co., Kansas, June 9, 1955, by C. C. Hall at Village Specialty Nursery.

Type host: Celtis sp. (Ulmaceae).

Relation to host: The leaves of the host are rough on upper surface and densely pubescent on lower surface. There is no apparent damage to the host. This species was also collected in Douglas Co., Kansas, Aug. 10, 1955, from the same host species.

Location of types: Female holotype and 10 paratype slides all from the type locality are deposited in Snow Entomological Museum, University of Kansas, Lawrence, Kansas. Dry leaves are in the writer's collection. One paratype slide with several specimens sent to U.S. National Museum.

Discussion: This species is fairly close to *Rhyncaphytoptus platani* Keifer but can be distinguished readily by the different shield pattern. It also has the habit of depositing eggs and molting on the tips of plant hairs. Some eggs and molting forms were also observed on the lower leaf surface, but more were seen on the ends of plant hairs.

This species is named for Dr. Jan Boczek, Warsaw Agricultural University, Warsaw, Poland. He showed me what was apparently the same species from *Acer* sp. in Poland and was kind enough to let me describe the species.

Rhyncaphytoptus platani Keifer
(Plate 32)

Rhyncaphytoptus platani Keifer, 1939, Bull. California Dept. Agr., 28:230.

Type locality: Sacramento, Sacramento Co., California.

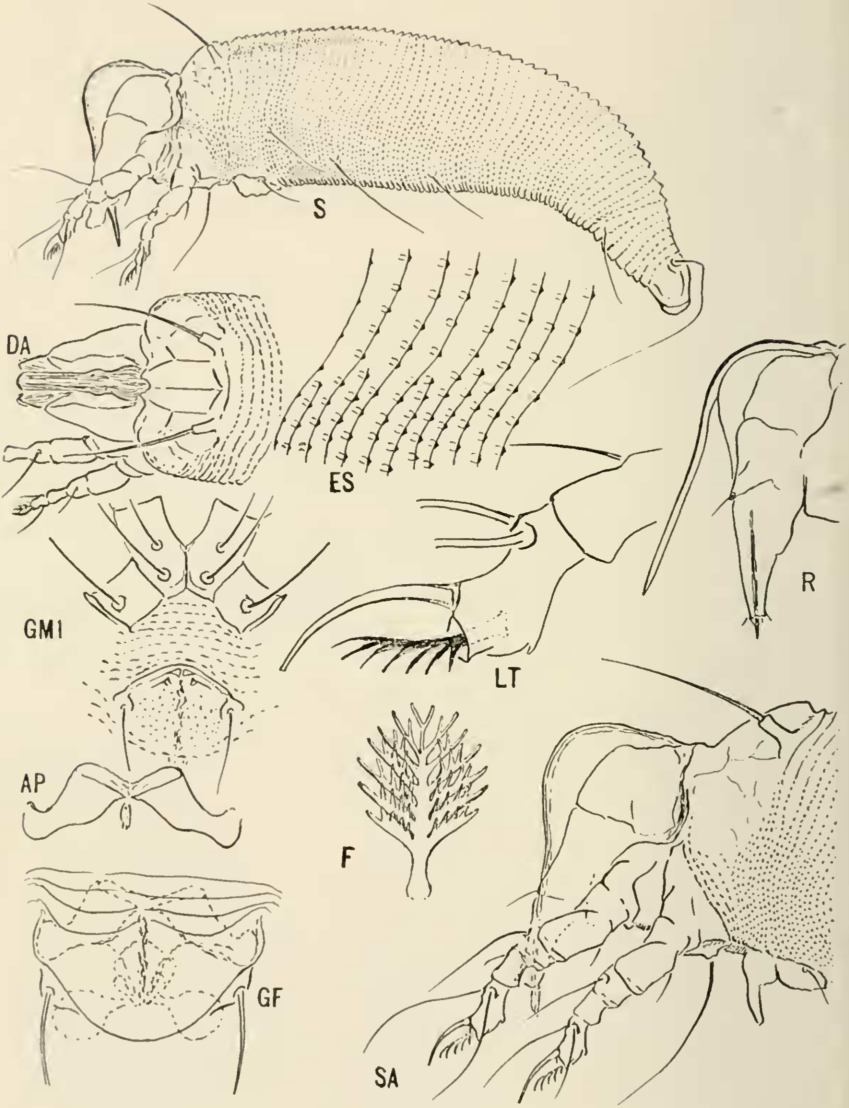
Type host: Platanus sp., a hybrid called "Oriental plane."

Additional hosts: Platanus racemosa Nutt., sycamore and *Platanus occidentalis* L., sycamore.

Relation to host: Mites live on the lower surface of the leaf and cause some browning of leaf tissue. In Kansas this vagrant species only lightly infests the lower surfaces of the leaf and causes no noticeable damage to the host.

Discussion: Rhyncaphytoptus platani and *R. megarostris* (Keifer) look similar. The chelicerae of *platani* seem to be more abruptly bent down than the chelicerae of *megarostris*. The tergites also seem a little wider in *megarostris*. The apodemes, featherclaws, shield pattern, and coverflap are strikingly similar in the two species.

Kansas record: Douglas Co., September 11, 1954, C. C. Hall (from *Platanus occidentalis* L.).



(Plate 32)

HOST LIST

The list below includes mite species associated with each host in Kansas.

Acer saccharinum L. (Aceraceae), white or soft maple

Vasates quadripedes Shimer .... plate 27

Agropyron smithii Rydb. (Gramineae), western wheat grass
Aceria tulipae (Keifer) .... plate 14
Vasates mckenziei Keifer .... plate 25
Allium cepa L. (Liliaceae), onion
Aceria tulipae (Keifer) .... plate 14
Buchloe dactyloides (Nutt.) Engelm. (Gramineae), buffalo grass
Aceria slykhuisi Hall .... plate 13
Carya sp. (Juglandaceae), hickory
Aceria erineus (Nalepa) .... plate 8
Carya illinoensis (Wang) K. Koch (Juglandaceae), pecan
Aceria caryae (Keifer) .... plate 5
Celtis occidentalis L. (Ulmaceae), hackberry
Aceria celtis (Kendall) .... plate 6
Rhyncaphytoptus boczeki .... plate 31
Cercis canadensis L. (Leguminosae), redbud
Vasates cercidis .... plate 21
Cynodon dactylon (L.) Pers. (Gramineae), bermuda grass
Aceria cynodonis Wilson .... plate 7
Distichlis spicata (L) Greene) (Gramineae), salt marsh grass
Vasates mckenziei Keifer .... plate 25
Fraxinus americana L. (Oleaceae), ash
Aceria nimia .... plate 12
Hordeum jubatum L. (Gramineae), barley
Aceria tulipae (Keifer) .... plate 14
Juglans nigra L. (Juglandaceae), black walnut
Apodiptacus cordiformis .... plate 30
Phyllocoptes microspinatus .... plate 18
Medicago satvia L. (Leguminosae), alfalfa
Aceria medicaginis (Keifer) .... plate 10
Morus sp. (Moraceae), mulberry
Aceria mori (Keifer) .... plate 11
Morus rubra L. (Moraceae), mulberry
Aceria lepidosparti Keifer .... plate 9
Opuntia sp. (Cactaceae), cactus
Aceria cactorum Keifer .... plate 4
Pinus sylvestris L. (Pinaceae), pine
Platyphytoptus sabinianae Keifer .... plate 19
Platanus occidentalis L. (Platanaceae), sycamore
Rhyncaphytoptus platani Keifer .... plate 32
Populus deltoides Marsh. (Salicaceae), cottonwood
Vasates dimidiatus .... plate 22

Salix sp. (Salicaceae), willow
- *Eriophyes laevis* (Nalepa) .... plate 16
- *Vasates laevigatae* (Hassan) .... plate 23
- *Vasates micheneri* .... plate 26

Solanum lycopersicum L. (Solonaceae), tomato
- *Vasates lycopersici* (Massee) .... plate 24

Sorgum halepense (L). Pers. (Gramineae), Johnson-grass
- *Abacarus sporoboli* Keifer .... plate 2

Tilia americana L. (Tiliaceae)
- *Phytoptus rotundus* .... plate 29

Ulmus americana L. (Ulmaceae), elm
- *Aceria parulmi* .... plate 3

Vitis sp. (Vitaceae), grape
- *Mesalox tuttlei* .... plate 20

Wheat (several varieties)
- *Aceria tulipae* (Keifer) .... plate 14

Yucca glauca Nutt. (Liliaceae)
- *Cecidophyopsis hendersoni* (Keifer) .... plate 15

APPENDIX

Mounting Media

Keifer's Solutions (Keifer, 1954)

First Solution:

Resorcinol	50 gms.
Diglycolic acid	20 gms.
Glycerin	25 cc.
Water	10 cc.
Iodine crystals	Enough to produce desired color

Second Solution:

Karo syrup (starch-free)	25 cc.
Chloral hydrate crystals	125 fms.
Glycerin	5 cc.
Water	15 cc.
Iodine crystals	Enough to produce desired color

Third Solution: (Final Medium)

Karo syrup	12 cc.
Chloral hydrate crystals	60 gms.
Potassium iodide crystals	Small amount to keep iodine in solution
Iodine crystals	2 gms.
Formaldehyde solution	Enough to form a thin mixture

CMC-10S—Stain-mountant. Available from Turtox biological supply house, 8200 S. Hoyne Ave., Chicago, Illinois 60620.

Nesbitt's Chloral Hydrate Clearing Solution (Nesbitt, 1945)

Chloral hydrate	40 gms.
Water	25 cc.
Hydrochloric acid	2.5 cc.

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